The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association

JANUARY 1949

American Volume

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ROENTGENOGRAPHIC CHANGES IN NAILED SLIPPED CAPITAL FEMORAL EPIPHYSIS *

BY ARMIN KLEIN, M.D., ROBERT J. JOPLIN, M.D., JOHN A. REIDY, M.D., AND JOSEPH HANELIN, M.D., BOSTON, MASSACHUSETTS

In a presentation made by the authors [3] before the American Medical Association, Section on Orthopaedic Surgery, in June 1947, were submitted the clinical results of

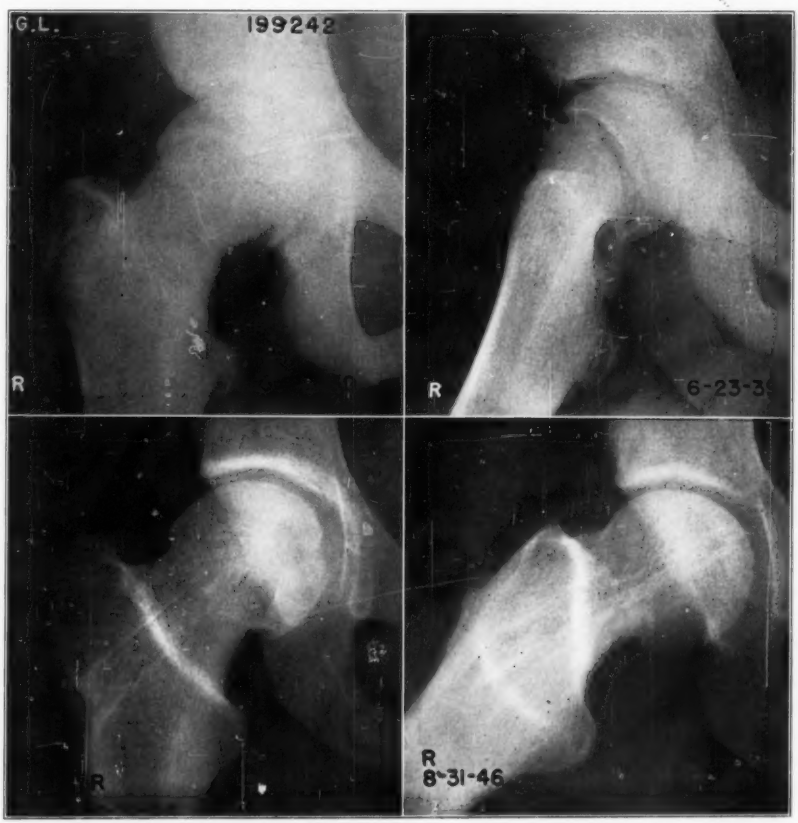

FIG. 1

Nailed *in situ*.

G. L., a girl, aged thirteen years and eleven months, was operated upon June 26, 1939. (The age of each patient represents the age at the time the first roentgenogram was taken.) A minimal amount of slipping had occurred. The nail was removed nineteen months after operation. Seven-year follow-up.

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

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FIG. 2

Nailed after epiphyseal osteotomy.

(The term "epiphyseal osteotomy" is used to designate the procedures of arthrotomy and osteotomy through the epiphyseal plate, prior to reduction.)

R. W., a male, aged fifteen years and three months, was operated upon September 22, 1942.

(*Continued on page 3*)

Fig. 2 (*Continued*)

Initial anteroposterior and lateral views, taken September 18, show slipping of 1.5 centimeters. Following satisfactory reduction and nailing, there is a defect visible at the superior junction of the head and neck. In the roentgenograms of April 13, 1946, this defect had filled in.

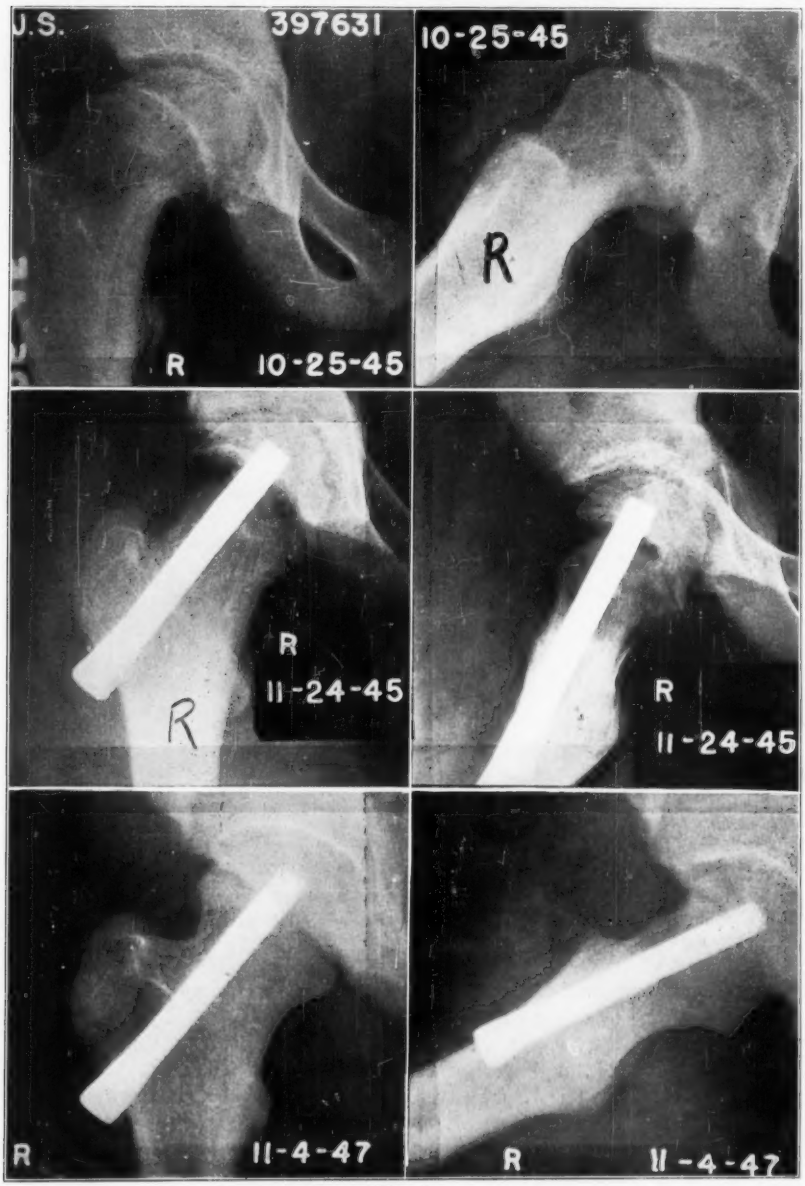

Fig. 3

Nailed after epiphyseal osteotomy.

J. S., a male, aged fifteen years and five months, was operated upon October 30, 1945. In roentgenograms taken November 24, reduction is satisfactory, but there is a large defect between the head and neck from unnecessary excision of part of the neck. On November 4, 1947, the defect had completely filled in.

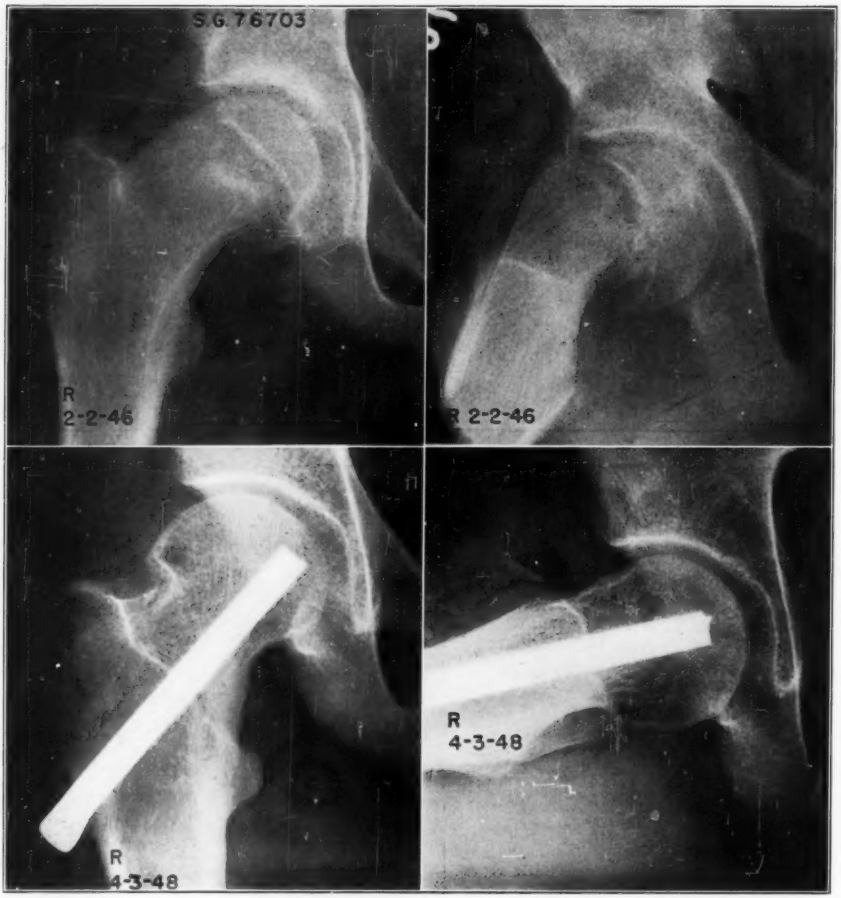

FIG. 4

Nailed after epiphyseal osteotomy.

S. G., a male, aged thirteen years and three months, was operated upon February 16, 1946. The marked slipping present on February 2 is seen to be satisfactorily reduced on April 3, 1948. Localized bone atrophy appears at the lateral superior aspect of the head in the anteroposterior view of April 3.

treatment by nailing in fifty-one cases of slipped capital femoral epiphysis. A roentgenographic survey of those cases is now presented.

The authors reported a study of thirty-one patients, four with bilateral involvement; this represented a total of thirty-five hips, nailed *in situ* because the amount of slipping had been less than one centimeter. After an average follow-up period of thirty-two months, the average index of motion was 90 per cent. of normal, and the average percentage of normal hip function was 96.

Determination of the index of motion, as stated previously by the authors[3], is as follows:

"As in our previous report[2], function of the hip was appraised by designating a factor for each motion according to its importance. The amount of demonstrable motion is multiplied by this factor to give a product for that particular motion. The sum of these products

FIG. 5

Nailed after epiphyseal osteotomy.

R. G., a male, aged thirteen years and seven months, was operated upon May 20, 1944. Marked slipping is demonstrable in the roentgenograms of May 13. Follow-up views four years later show good reduction. Localized bone atrophy appeared at the anterior superior aspect of the head following operation.

represents the 'index of motion' [1]. An example of the use of the index of motion in a specific case follows:

	Motion, Degrees	*Factor*	*Product*
Flexion	145	0.4	58
Abduction	45	0.4	18
Adduction	30	0.2	6
Rotation			
Internal	30	0.2	6
External	60	0.1	6
Extension	10	0.1	1
			95

FIG. 6

Nailed after epiphyseal osteotomy.

W. R., a male, aged fourteen years and eight months, was operated upon April 7, 1945. There was marked slipping initially, which was reduced satisfactorily. The nail was removed on December 14. Calcification appeared in the anterior capsule following operation.

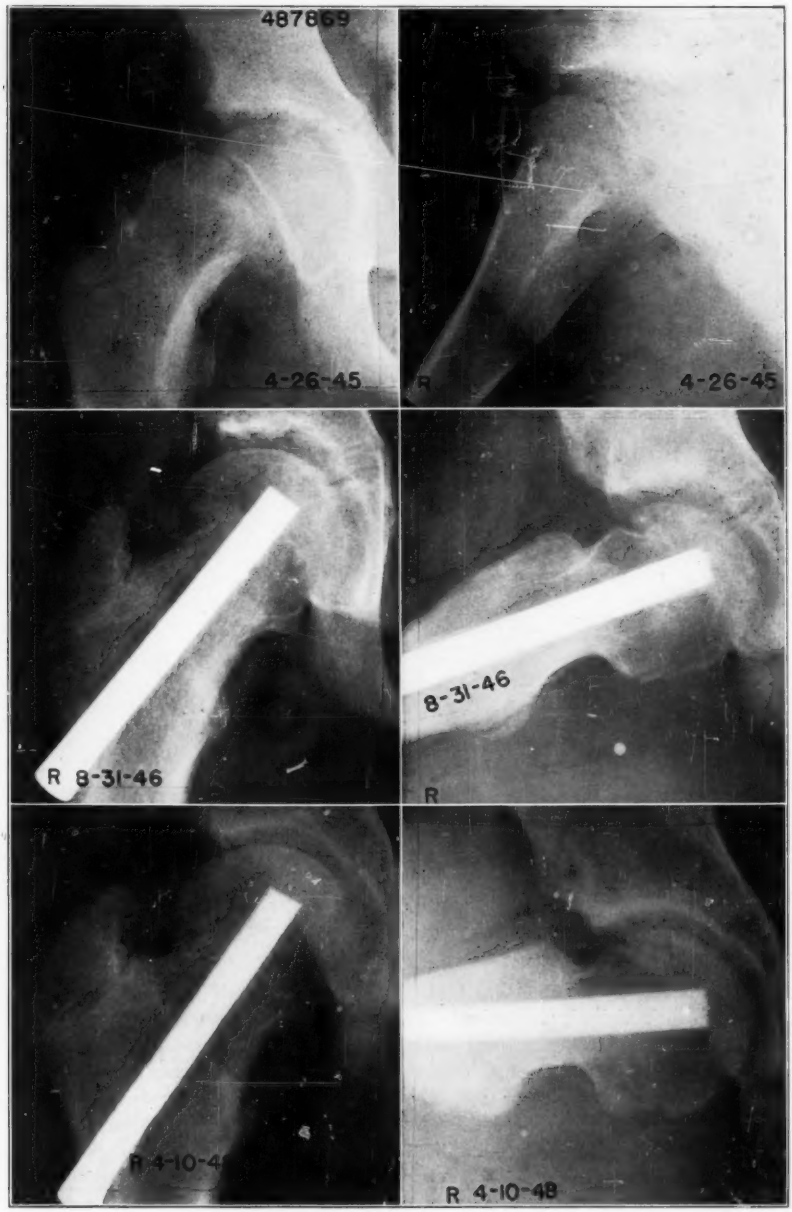

FIG. 7

Nailed after epiphyseal osteotomy.

R. P., a male, aged thirteen years and three months, was operated upon May 21, 1945. The initial films, taken April 26, 1945, show marked slipping. On August 31, 1946, following replacement of the head, a prominent defect was visible, both superiorly and inferiorly, at the junction of the femoral head and neck. On April 10, 1948, the defects had largely filled in, with virtual restoration of normal smooth contours.

FIG. 8

Nailed after epiphyseal osteotomy.

M. W., a girl, aged twelve years and ten months, was operated upon May 1, 1945. In the roentgenograms taken on April 26, slipping was marked. On December 23, 1947, reduction was satisfactory.

"On this basis, the index of hip motion was then computed for the affected hip as compared with the sound hip. Since such an index of motion does not include pain or limp, we assigned equal value to the index of motion, absence of pain and absence of limp, calling the average of these the percentage of true normal function of the hip."

The roentgenograms taken at the end of a seven-year follow-up period (Fig. 1) indicate the results that can be expected from nailing *in situ*, when the minimal amount of slipping is detected early. Early mobilization and active weight-bearing on crutches within two or three weeks after operation promote preservation of the physiological function of the hip. In this series of cases, in which nailing was done *in situ*, traumatic arthritis or aseptic necrosis of the femoral head has not occurred.

Sixteen patients were reported with marked slipping (more than one centimeter). They were treated with arthrotomy, osteotomy through the epiphyseal plate, replacement of the head to its anatomical position in relation to the neck, and lateral nailing for fixation. After an average follow-up period of thirty-three and one-quarter months, the average index of motion was 85 per cent. of normal, and the average percentage of normal hip

FIG. 9

Nailed after epiphyseal osteotomy.

P. A., a male, aged fourteen years and four months, was operated upon September 24, 1945. Marked slipping was present initially, with good reduction evident in the two-year follow-up. A small circular calcification may be seen in the anterior capsule in the postoperative roentgenograms.

function was 92. Roentgenograms (Fig. 2) depict the results obtained by a restoration of the physiological function of the hip, achieved through replacement of the disrupted parts and early postoperative mobilization.

The condition of a male, aged fifteen, who had had an open reduction and nailing of his right hip, is illustrated in Figure 3. The postoperative roentgenograms, taken on November 24, 1945, show that a portion of the neck at the epiphyseal plate had been osteotomized. This procedure was carried out in the hope of simplifying replacement of the head. Excision of this portion of the neck, however, made realignment of the head more difficult, because of the loss of an important landmark to guide replacement. After replacement, a large defect in the neck is obvious at the site of osteotomy. Fortunately, in this case the defect filled in, as shown in the lower section of Figure 3, which consists of roentgenograms taken two years later. This patient's hip eventually attained an index of motion of 88 and a percentage of function of 95.

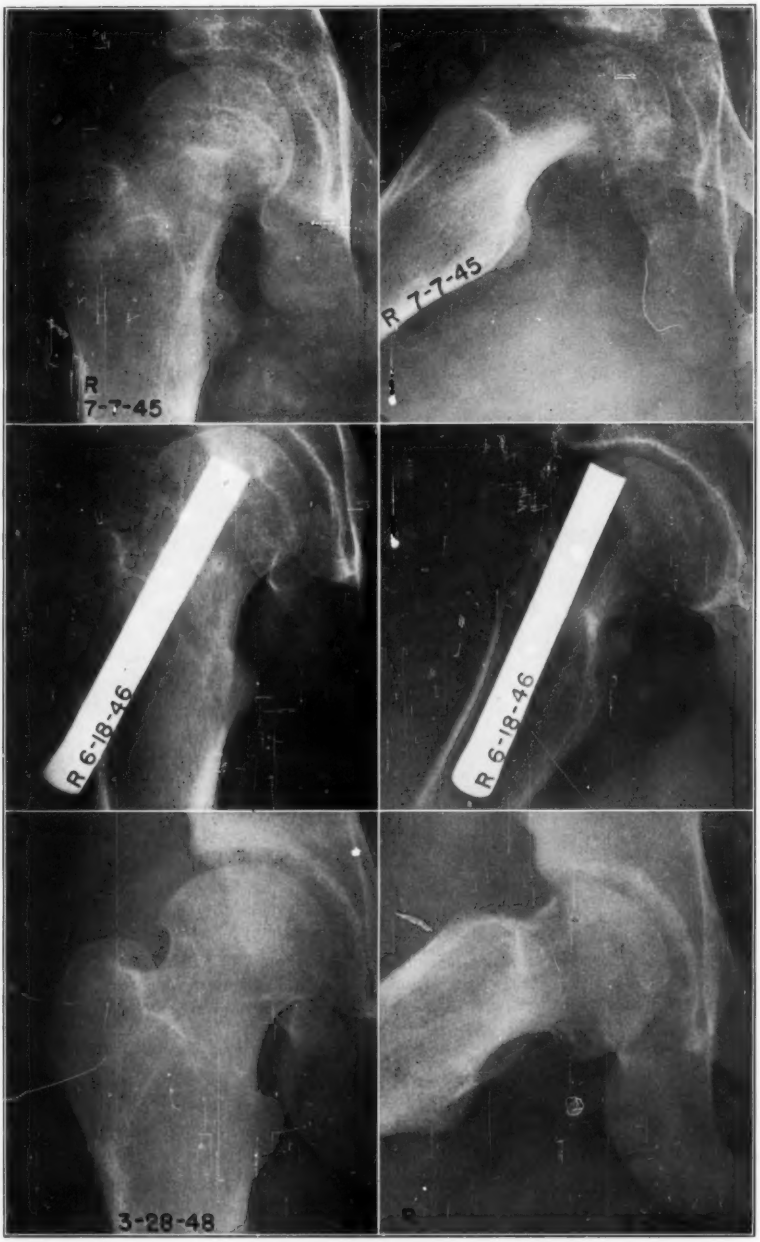

FIG. 10

Nailed after epiphyseal osteotomy.

G. G., a male, aged fourteen years and eleven months, was operated upon July 14, 1945. Marked slipping was visible in the initial views of July 7, 1945. Satisfactory reduction was shown on June 18, 1946. The nail was removed thirteen months after operation.

FIG. 11

Nailed after epiphyseal osteotomy.

A. C., a male, aged twelve years and five months, was operated upon September 20, 1945. Anteroposterior and lateral views, taken September 19, showed fairly marked slipping, which was satisfactorily reduced, as seen in the views of April 10, 1948.

To obtain early motion, active weight-bearing on crutches is permitted within two or three weeks after operation, when muscle spasm about the involved hip has decreased. Figures 4 through 13 indicate that replacement of the head to its normal valgus relationship with the neck can be effected only at the site of the original displacement,—namely, the epiphyseal plate.

We should now like to emphasize that there are two additional basic requirements necessary to obtain the results shown. First, the hip should be approached through an incision [4] that gives sufficient exposure to permit replacement of the head. Second, the hip joint should be entered through an incision (Fig. 14) across the capsule, over the anterior portion of the epiphyseal plate. This spares the ligamentum teres and the posterior, superior, and inferior portions of the visceral capsule. The osteotomy is performed through the epiphyseal plate, which is avascular, without any of the neck being sacrificed. These details minimize the possibility of damage to the circulation of the head. Thus we replace the head to its normal position, its margins draped anteriorly and laterally beyond the neck, with a minimal amount of damage to the epiphyseal circulation; and we stress im-

mediate postoperative active mobilization of the restored hip. Adherence to these fundamentals minimizes the possibility of aseptic necrosis of the femoral head, either alone or in association with traumatic arthritis.

In this series, traumatic arthritis has been encountered in only two cases, as follows:

J. A., a male, aged fifteen, had a marked amount of slipping, as shown in Figure 15, upper views. The condition was treated by arthrotomy with satisfactory reduction, but with improper placement of the nail for fixation. Four years later, there was obvious traumatic arthritis, probably due to the anterior projection of the nail through the head.

C. J., a boy, aged eleven, was treated by open reduction and nailing of the left hip, in July 1933. (Unfortunately, the early roentgenograms were destroyed.) Reduction was incomplete. A plaster spica was applied eighteen days after operation and was kept on for three months. The nail was removed six months later. The anteroposterior view in 1940, seven years after operation (Fig. 16), shows that the head of the left femur was irregular and that the neck was shortened and broadened. There were several rarefied areas in the head and neck. In the two center views, thirteen years after operation, the rarefied zones appeared to have filled in partially with new bone. In the last eight-year period of observation, as shown in the roentgenograms (Fig. 16, lower views), the anticipated progression in the degree of arthritic change has not occurred. This patient obtained a rather satisfactory functional result, despite two errors in treatment,—namely, apparent inaccurate reposition of the head on the neck and unnecessary immobilization in a plaster spica.

The authors believe that if the slipped capital femoral epiphysis is treated by nailing, either *in situ* or after open reduction with replacement at the epiphyseal plate, depending upon the degree of slipping, the danger of further

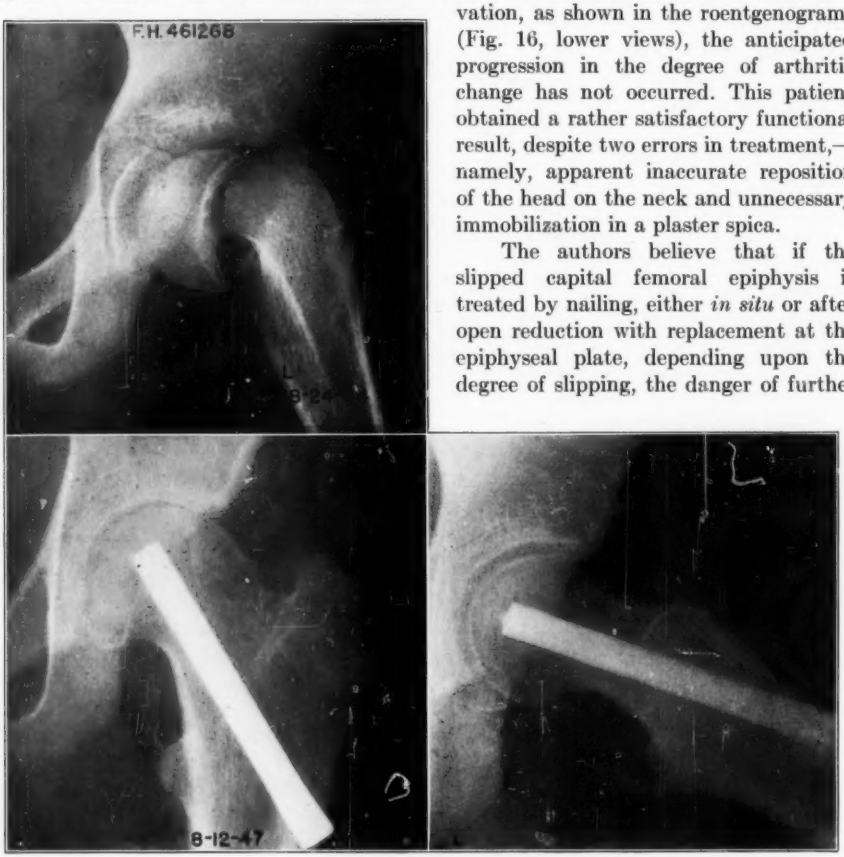

FIG. 12

Nailed after epiphyseal osteotomy.

F. H., a male, aged thirteen years and nine months, was operated upon September 8, 1944. Extreme slipping was present on August 24. Three years later there had been virtual anatomical restoration.

slipping is eliminated. Furthermore, the patient can be returned to his normal environment within two or three weeks, walking with crutches; and within two months he is able to walk without extrinsic support.

The authors have noted roentgenographic evidence of fusion of the epiphysis within four to eight months after nailing in the open-reduction cases and within six to eighteen months in the cases nailed *in situ*. In the latter group, the nailed epiphysis fused eight to twenty-one months sooner than that on the uninvolved side. With open reduction, the nailed epiphysis fused five to thirty-five months before that on the uninvolved side. Apparently, osteotomy through the epiphyseal plate accelerates fusion more rapidly than fixation by nailing *in situ*.

The nail should not only cross the epiphyseal plate, but should extend well into the head. In four cases nailed *in situ*, growth continued away from the end of the nail (Figs. 17, 18, and 19). None of these patients had any complaints, and no further slipping or shortening resulted.

FIG. 13

Nailed after epiphyseal osteotomy.

S. P., a male, aged fourteen years and seven months, was operated upon October 31, 1941. Severe slipping, demonstrable in the roentgenograms of October 29, 1941, had been satisfactorily reduced, as shown in the six-year follow-up views.

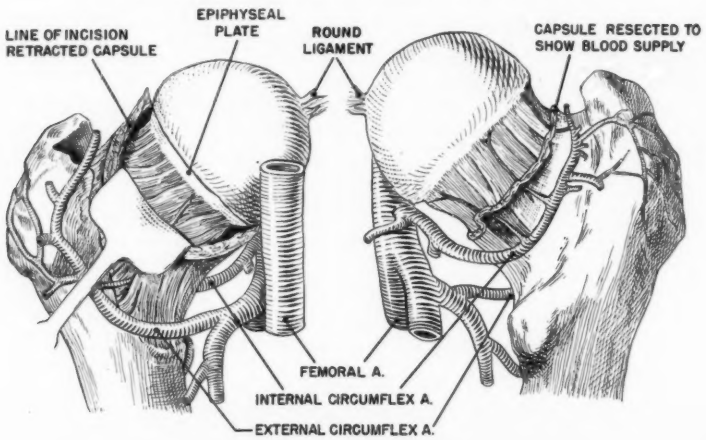

FIG. 14

Schematic drawing showing blood supply to the femoral head and neck.

FIG. 15

Nailed after epiphyseal osteotomy.

(*Continued on page 15*)

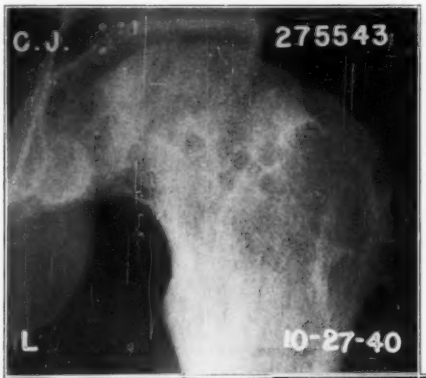

Fig. 15 (*Continued*): J. A., a male, aged fifteen years and three months, was operated upon May 1, 1944. Marked slipping, present on April 4, 1944, had been reduced by January 15, 1948. Here the nail, shown in the anteroposterior view to be apparently well placed, in the lateral view projects through the anterior cortex of the head. There is considerable irregularity of the articular margin of the head and, to a lesser degree, of the acetabulum. Faulty placement of the nail apparently is the major factor in the production of the traumatic arthritis.

FIG. 16

Nailed after epiphyseal osteotomy.

C. J., a male, aged eleven years and seven months, was operated upon July 7, 1933. (The early roentgenograms were destroyed.) The nail was removed six months after operation. The anteroposterior view on October 27, 1940, showed shortening and broadening of the femoral neck and deformity of the femoral head with irregularity of the articular margin, indicative of traumatic arthritis. In the reproduced films taken at the end of the last eight-year period of observation, no obvious progression of the traumatic arthritis was evident.

In two cases there was slipping of the upper femoral epiphysis of more than one centimeter, but nailing was carried out *in situ* (Figs. 20 and 21). Although these patients now

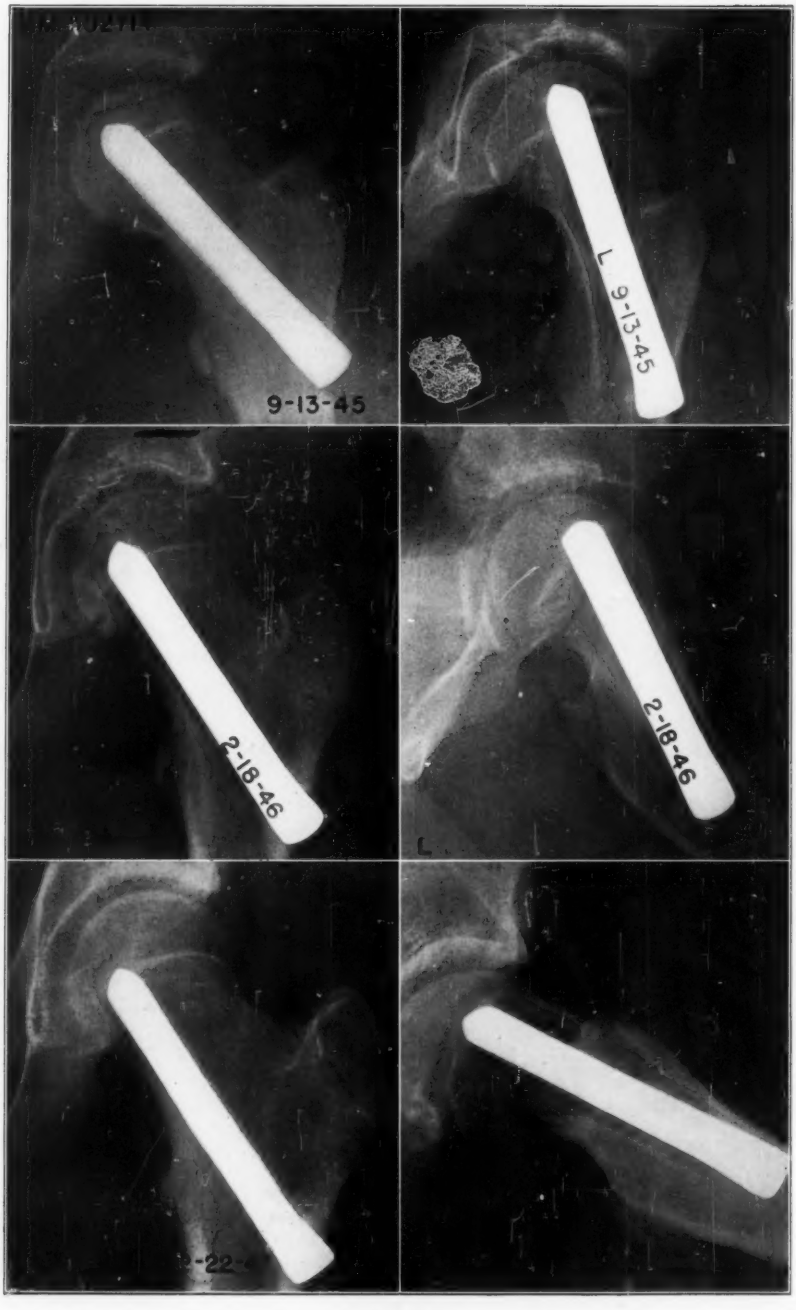

FIG. 17
Nailed *in situ*.
(*Continued on page 17*)

Fig. 17 (*Continued*)

J. M., a girl, aged eleven years and nine months, was operated upon September 6, 1945. In the serial anteroposterior and lateral roentgenograms, covering a period of twenty-seven months, a progressive change occurred in the relative position of the nail to the epiphyseal plate. This indicates that epiphyseal growth was not arrested by the nailing procedure. No further slipping occurred. The central part of the epiphyseal plate showed fusion in the films of December 22, 1947.

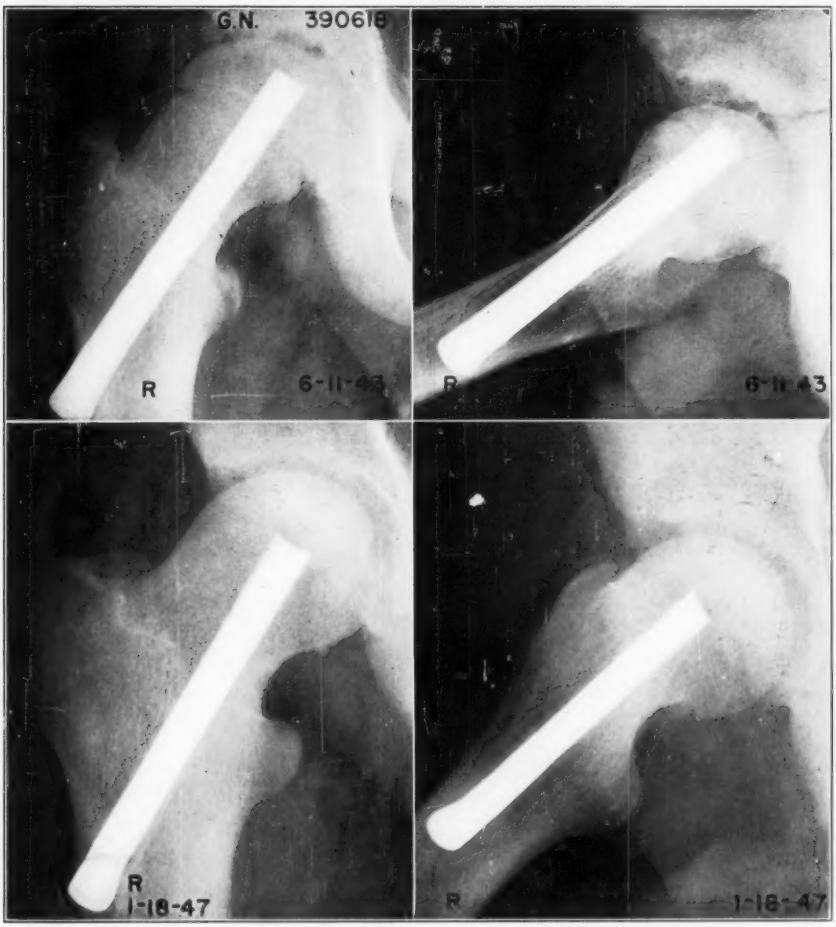

Fig. 18

Nailed *in situ*.

G. N., a male, aged twelve years and eight months, was operated upon February 5, 1943. Nail is shown, in films of June 11, 1943, to be correctly placed. Epiphyseal growth continued. The four-year follow-up views show the nail completely distal to the epiphyseal plate. No further slipping occurred.

have excellent function, an open reduction with replacement of the head to a more valgus position on the femoral neck might have prevented the obvious residual deformities which may very well be the precursor of traumatic arthritis.

SUMMARY

Roentgenograms have been presented to illustrate:

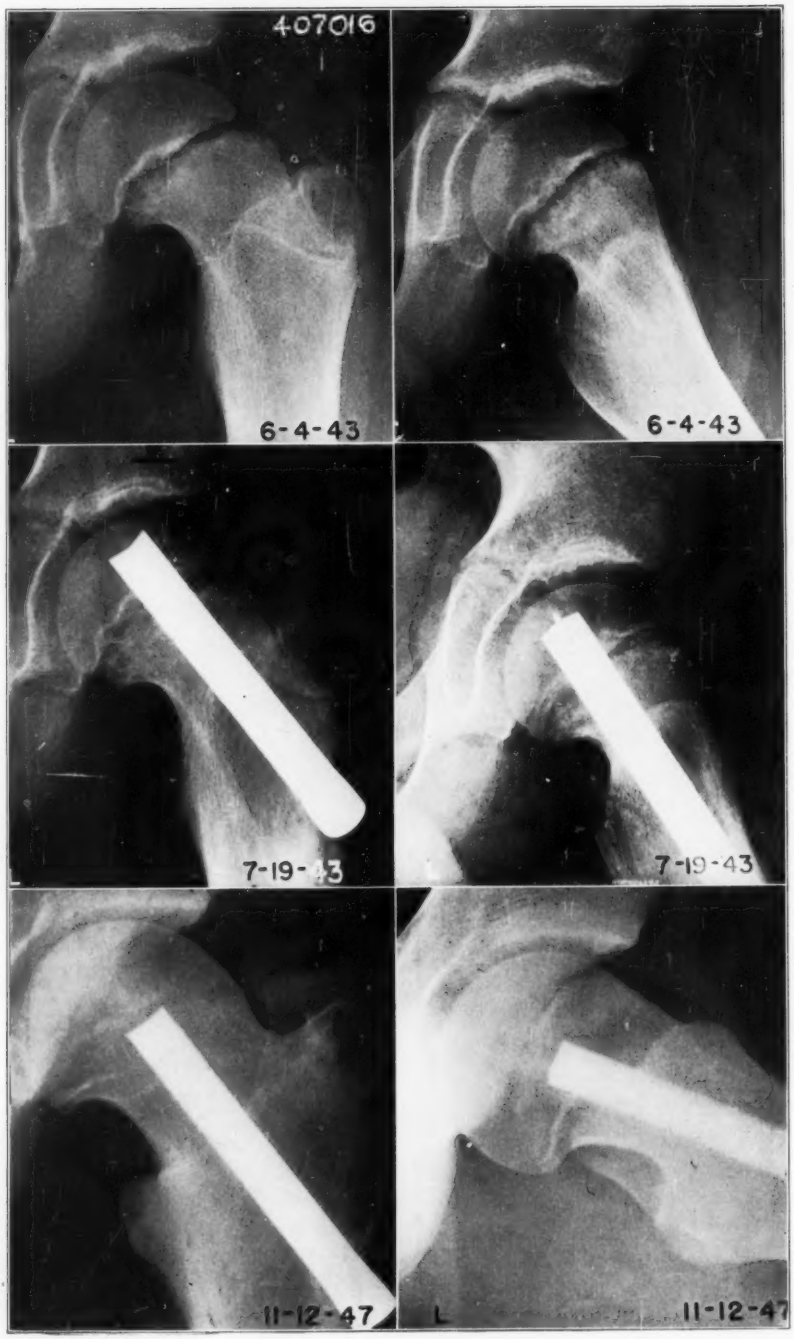

FIG. 19

Fig. 19
Nailed *in situ*.

R. S., a male, aged eleven years and eight months, was operated upon June 7, 1943. Growth continued at the epiphyseal plate, following correct placement of the nail, as shown in roentgenograms taken on July 19, 1943. By November 12, 1947, the nail was completely distal to the epiphysis. No further slipping occurred.

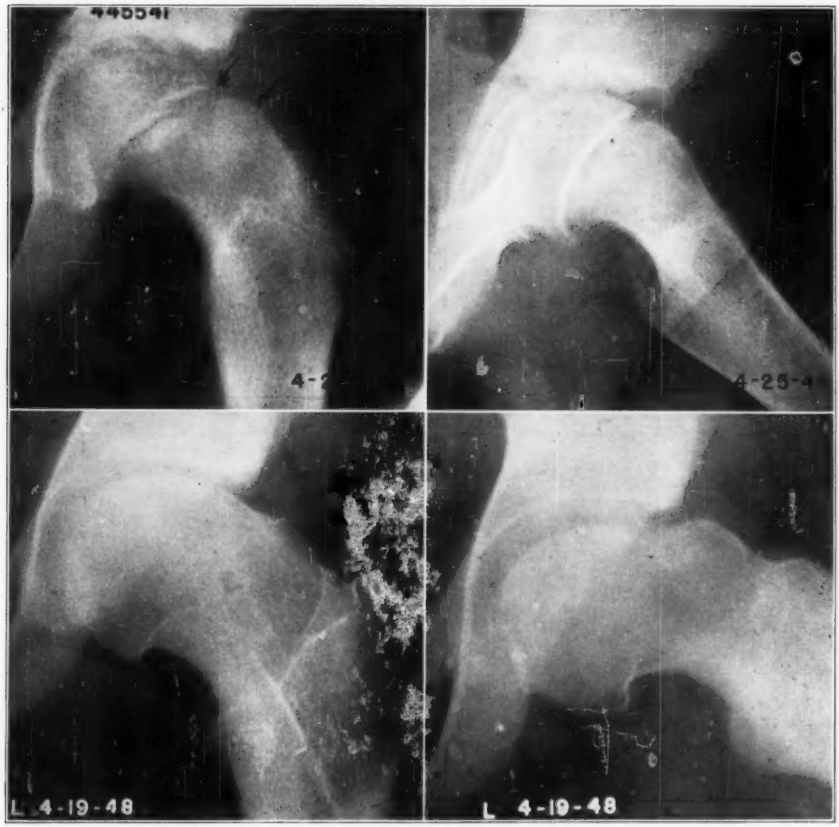

Fig. 20
Nailed *in situ*.

F. R., a male, aged thirteen years and two months, was operated upon May 6, 1944. On April 25, the slipping was approximately 1.5 centimeters. Arthrotomy, osteotomy at the epiphyseal plate, and replacement before nailing would have prevented the residual deformity at the anterior superior junction of the head and neck, as seen in the follow-up views. The nail was removed twenty months after operation.

1. The results of the treatment of slipped capital femoral epiphysis by nailing *in situ* and by nailing after osteotomy and replacement.

2. The prevention of further slipping, acceleration of fusion of the epiphysis, and preservation of a relatively normal anatomy of the hip, accomplished by this method.

3. The absence of the accelerated fusion in four cases, in which growth persisted until the epiphyseal plate had advanced beyond the end of the nail.

The results of this method of treatment suggest that adequate replacement with a

FIG. 21

Nailed *in situ*.

A. W., Jr., a male, aged thirteen years and four months, was operated upon April 28, 1941. Initial anteroposterior and lateral views, taken on April 17, 1941, showed slipping of approximately 1.5 centimeters. By our present standards, this patient should have been treated by arthrotomy, osteotomy at the epiphyseal plate, and replacement before nailing. This would have prevented the prominent bony projection at the superior junction of the head and neck, obvious in the films of May 29, 1946.

minimal amount of circulatory embarrassment to the femoral head and neck, followed by early mobilization and weight-bearing with the aid of crutches, is of paramount importance.

Treatment of the slipping while it is minimal permits a simpler operative procedure with an excellent prognosis, and eliminates the hazards and the inferior results stemming from the difficult procedure which is indicated after the slipping has become marked.

REFERENCES

1. FERGUSON, A. B., and HOWORTH, M. B.: Slipping of the Upper Femoral Epiphysis. A Study of Seventy Cases. J. Am. Med. Assn., **97**: 1867–1872, 1931.
2. KLEIN, ARMIN; JOPLIN, R. J.; and REIDY, J. A.: Treatment in Cases of Slipped Capital Femoral Epiphysis at the Massachusetts General Hospital. Arch. Surg., **46**: 681–686, 1943.
3. KLEIN, ARMIN; JOPLIN, R. J.; and REIDY, J. A.: Treatment of Slipped Capital Femoral Epiphysis. J. Am. Med. Assn., **136**: 445–449, 1948.
4. SMITH-PETERSEN, M. N.: Arthroplasty of the Hip. A New Method. J. Bone and Joint Surg., **21**: 269–288, Apr. 1939.

DISCUSSION

NOTE: The Discussion concerns a group of papers on the treatment of slipped epiphysis, presented at the same session. The other three were:
"The Management of Incipient Epiphyseolisthesis of the Hip" by Samuel Kleinberg, M.D., New York, N. Y.
"Slipping of the Upper Femoral Epiphysis" by Beckett Howorth, M.D., New York, N. Y.
"Treatment of Slipping of the Upper Femoral Epiphysis. A Study of the Late Results in Forty-two Cases" by Clarence H. Heyman, M.D., Cleveland, Ohio.

DR. PHILIP D. WILSON, NEW YORK, N. Y.: There is nothing new about the etiology of this condition. The endocrine factor is still discussed, but no clear evidence has been produced to show that it plays any part. It is true that many of the patients are overweight and that they often show signs of endocrine dysfunction, but I think we may conclude that the extra weight is the chief factor, because it overloads the epiphyses. There is no evidence that treatment along endocrinological lines will make any difference. As a matter of fact, if these patients are treated by various types of sex hormones, the effects upon the precocious development of the secondary sexual characteristics, as well as the accompanying changes, are often so troublesome that it seems to me the orthopaedic treatment is preferable and far more certain. The average age of these patients, as stated by the authors, is the same as I found in a previous study: thirteen and one-half years for the boys and eleven and one-half years for the girls. I think that this has no bearing on the possible endocrine relationship, as it is well known that the growth rate in girls is more rapid and that their epiphyses mature at an earlier age than in boys.

I believe that nothing new has been shown in relation to the pathological changes that occur with epiphyseal displacement.

As far as treatment is concerned, I think we are all agreed upon the need for early recognition and diagnosis of these cases before displacement of any extent has taken place. Most of these patients are first seen by the family physician, and the only way we can help is by improving medical education. We know of the increasing demands that are being made upon the medical schools to include additional material in their curricula. It seems to me that one criterion which might be applied is whether or not the teaching is of fundamental importance; and that when early diagnosis and treatment are so important and make such a difference in the final result in slipping of the upper femoral epiphysis, it should be stressed to the medical student in such a way that he will never forget to look for it. Speaking as a representative of the City of New York, I am glad to say that there has been a great improvement in the early diagnosis and recognition of these cases. Our experience over the last ten years shows that at least two-thirds of these cases are seen in hospital clinics when slipping is minimal, and we feel that it is not necessary to correct the deformity. We treat these cases as emergencies and have them admitted to the hospital immediately, where fixation of the epiphysis is carried out with a Smith-Petersen nail. We send them home from the hospital in about two weeks, walking with crutches and with an elevation under the shoe on the uninvolved extremity.

As far as manipulative reduction of the deformity is concerned, the only advocate for this method among the speakers is Dr. Heyman, who reports good clinical results in seventeen of twenty-one patients, but good roentgenographic improvement only in fourteen. He thinks that the fixed external rotation and limitation of abduction are often due to contracture of the muscles and ligaments, rather than to bone deformity. I'm sure we would all agree with him that muscle contracture and spasm play a part in limiting the motion, but I think that this is not true when the roentgenogram shows bone deformity. In old healed cases with displacement we find similar limitation, and that is undoubtedly due to the bony obstruction. He finds this is true also in these cases, because these are the ones in which he has removed surgically the bony obstruction to motion.

A great many of the older surgeons in the audience were brought up on the manipulative treatment of slipped femoral epiphysis, followed by immobilization in a plaster spica; most of them have abandoned this treatment, and we should ask why. Speaking as an individual, my own experience has convinced me that I often fooled myself and thought I had accomplished reduction when such was not the case. Waldenström explained this by showing a specimen he had recovered from a child with slipping epiphysis, who had been subjected to manipulation and fixation in plaster. The roentgenogram seemed to show reduction, but when the child died of some extraneous condition and the specimen was recovered, he found that the deformity was the same as it had been originally. Also, in some of my cases, avascular necrosis of the epiphysis developed after manipulation, and I was convinced that my efforts to obtain wide abduction and internal rotation had injured the vessel-bearing tissue of the capsule to such an extent that necrosis resulted. Furthermore, I believe too much consideration should not be given to the results, unless these cases have been followed for many years. From experience with older cases in which osteo-arthritis has developed, we can see that the patients apparently did well for a number of years following their treatment before they began to complain of pain, and yet by roentgenographic study we see that they have had gross deformity of the femoral neck all the time.

The other speakers have advocated various methods to secure internal fixation of the epiphysis and early healing. There are those who favor the Smith-Petersen nail; others use various types of pins; and Dr. Howorth and his associates have employed small bone grafts, driven up into the head through drill holes. I do not suppose we are ever going to reconcile our differences with regard to technique, nor do I believe that it is

really important, because all of us are aiming to accomplish the same thing by different methods,—namely, fixation of the epiphysis and early mobilization. I am perfectly willing to accept Dr. Howorth's operation, but it seems to me that the nail accomplishes the same thing, more simply and with less risk. If the epiphysis is properly fixed through the femoral neck, it will heal as rapidly with the nail as with the graft, and less harm is done to the bony structure. I have seen bad results from nailing, but because the operation had been done improperly. There is need for a good technique in introducing and placing the nail accurately. This is a matter that calls for teamwork between the surgeon and the roentgenologist, but I am sure that it can be done.

We have used, at the Hospital for Special Surgery, about the same after-treatment as Dr. Kleinberg has described. We have a series of over seventy cases with minimal deformity that had been treated by simple nailing. There was one case with avascular necrosis, but this was due to the fact that the epiphysis had been driven away from the neck when the nail was introduced. I think that can be avoided if one studies the roentgenograms carefully. When one notes a wide separation of the epiphysis from the neck and an appearance of considerable instability, then one should introduce a guide pin to fix the epiphysis and employ a cannulated nail, or one can use a lag screw. We had one case of infection with a bad result. I would stress the need for avoidance of unnecessary damage to the bone structure in introducing the nail. If one drives the nail in and takes it out and repeats this performance several times, there is great damage to the internal cancellous structure of the neck, and it may have an effect upon the blood supply to the epiphysis. I quite agree with Dr. Heyman that this is not desirable and that it affects the result.

We must now consider what to do in the cases with deformity and displacement. Should we attempt open reduction by epiphyseal osteotomy or by transcervical osteotomy? Of course, in an early case we may employ traction, but I am assuming that we are discussing cases in which the epiphysis is united, with resulting deformity. I believe that open reduction is indicated only in the acute cases in which the epiphysis is widely displaced and reduction is not obtained by traction. In 1927, I reported a group of cases with displacement in which I had separated the epiphysis from its deformed position, replaced it on the neck, and fastened it with a nail. The results in these cases were good; but later, when I did more of them, I began to encounter avascular necrosis of the epiphysis and I gave up the method. I then favored accepting the intra-articular deformity and correcting the position of the limb by a subtrochanteric osteotomy. Later, however, at the Hospital for Special Surgery, I observed the cases in which Dr. Lewis Clark Wagner had corrected the deformity by cervical osteotomy, and he convinced me that this is a very good procedure and that the results are satisfactory. Dr. Carl Badgley has also reported good results from this method.

There is one point that I consider important in the operative approach to these hips,—namely, that the reflection of the capsule from the base of the neck impairs the blood supply to the epiphysis, and therefore should be avoided. With a transverse incision close to the anterior rim of the acetabulum, there is less danger of doing damage to the blood supply.

Many surgeons have noted the development of arthritis in the hips of patients with epiphyseal displacement, following operations to correct the deformity. In such cases there is no actual necrosis of the epiphysis or absorption of it, but the joint cartilage space becomes narrowed and the hip becomes fixed. I have performed arthroplasty in some of these cases later, and this has given me the opportunity of examining the head by microscopic section. I am convinced that the loss of the joint cartilage is the result of a limited or partial avascular necrosis, which is followed by revascularization in the subchondral area of the bone. This has been shown beautifully in some of the sections.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: I became interested in slipping of the upper femoral epiphysis in 1920, and studied the cases at the Massachusetts General Hospital. That study was published in 1926. The pathological changes in the bone had been well worked out before 1900. Sprengel and other German surgeons had noted the changes in the epiphyseal line, shortening of the femur, and displacement of the head that are now being described to us. I think that the changes in the synovial membrane have not been noted before.

In none of the cases that we treated by manipulation could any reduction of the deformity be demonstrated; in other words, we were working on a cap that was firmly fixed to the neck, and all we did by manipulation was to traumatize the articular surface. Dr. Carl Badgley later opened some of these hips, after unsuccessful manipulation, and saw evidence of injury to the cartilage.

I am at a total loss to explain the good results by manipulation, except by the fact that this is a condition of adolescence in which bad results are not evident until middle life. The fact that these individuals do not have pain or disability a few years afterward means nothing. On the other hand, if these hips were examined carefully, limitation of motion and incongruity of the joint surfaces would probably still be found; and where there is incongruity of the joint surfaces in the hip, arthritis will develop after the individual uses that hip for a number of years.

I believe that neither drilling, as Dr. Kleinberg did, nor nailing, nor the use of three bone pegs or one bone peg across the center of the epiphyseal line can be depended upon to fuse the epiphysis. Dr. Phemister, in his operation for stopping bone growth, went to a great deal of trouble not only to curette the center of

(Continued on page 54)

DELAYED AUTOGENOUS BONE GRAFT IN THE TREATMENT OF CONGENITAL PSEUDARTHROSIS*

BY JOHN ROYAL MOORE, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Orthopaedic Surgery, Medical School of Temple University, and Shriners' Hospital for Crippled Children, Philadelphia

The etiology of congenital pseudarthrosis still remains obscure, in spite of the diligent work of numerous investigators, here and abroad, during the past century. Among various etiological hypotheses proposed are trauma to the foetus, exogenous and endogenous; osseous disease of the skeleton, intrauterine rickets, osteomalacia, chondromalacia, and osteitis; disease of the amnion, anhydramnion, amniotic bridle (amniotic-band adhesion), Seminartes ligaments (amniotic bands), and amniotic compression; vascular dysplasia [3, 11]; osteopathy, due to lesions of the central nervous system; arrest of development and mesenchymal hypoplasia [3, 11]; neoplasm and neurofibroma [16]. Tillier in 1928, Ducroquet in 1937, Barber in 1939, and B. H. Moore in 1940 pointed to the frequency with which mollusca, neurofibroma, and café-au-lait spots are found in association with congenital pseudarthrosis and other congenital anomalies. Congenital pseudarthrosis is rare in comparison with other congenital anomalies. Camurati noted twenty-seven cases at the *Istituto Rizzoli* in thirty-two years. The principal site of election is the lower third of the tibia or fibula (slightly more often on the left side than on the right), but the condition has been encountered in other bones of enchondral origin, including the clavicle, humerus, ulna, first rib, and femur. Heredity has been reported a factor in two cases [9]. The lesion is slightly more frequent in the male (57 per cent.) than in the female (43 per cent.).

These statistics and part of the historical data cited were obtained from a study by Mario Camurati of 118 cases collected from the literature or observed at the *Istituto Rizzoli*, reported in 1930.

The histopathological characteristics of the lesion have been generally accepted as conforming to those of acquired pseudarthrosis. Inert, sclerosed, pointed, atrophic bone ends (having the appearance of sucked candy), surrounded by a sleeve of dense connective tissue and developing ultimately the characteristics of a nearthrosis including the cartilage and joint cavity, are the principal findings in the mobile type. Green and Rudo, in 1943, reported the finding of a neurofibroma at the site of a congenital pseudarthrosis of the tibia. This startling discovery did much toward awakening interest in the pathology and etiology of this disease, but to date there has been little confirmation in the literature.

The early treatment of congenital pseudarthrosis included the use of setons by Physick in 1820, as described by Ker; injection of such irritating substances as iodine; injection of whole blood; ignipuncture, splints, continuous traction, amputation, and braces. Reichel, in 1902, raised a pedicle graft from the opposite tibia (graft and periosteum were attached to the overlying subcutaneous tissue and skin), crossed the legs, and attached the free surfaces of the pedicle to the exposed pseudarthrosis site by periosteum and skin. The skin and subcutaneous tissue of the flap were returned to the original bed in twenty days. Success was reported. This method was adopted for a time by Codivilla, Coenen, and Nové-Josserand. Codivilla later (in 1906) employed long, narrow osteoperiosteal grafts in barrel-stave fashion. Tillier, in a report in 1928, cited several successes with the Curtillet method and recommended arterial sympathectomy in instances of slow consolidation. Froelich, in 1910, recommended massive osteoperiosteal grafts.

The history from 1910 until the present period records the continuation of surgical

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1948.

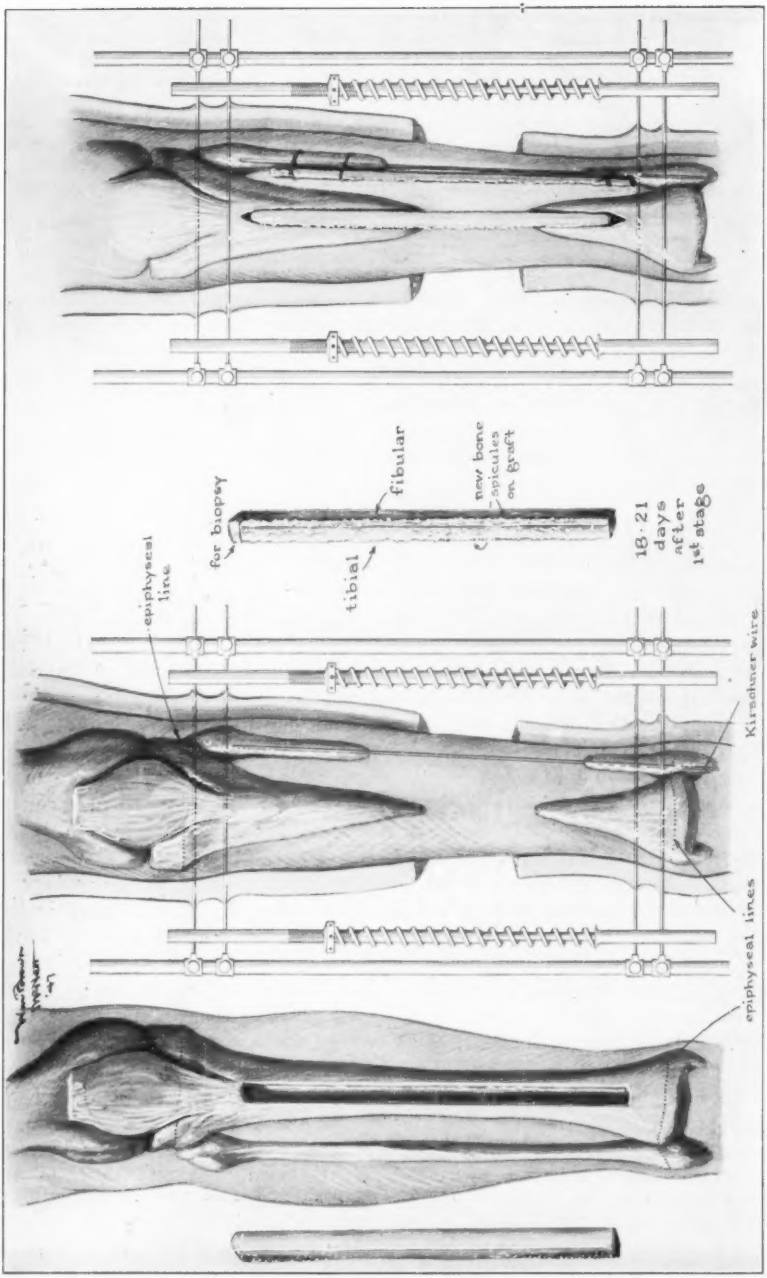

FIG. 1

Schematic drawing of the first and second stages of the delayed graft. Shows the employment of the lengthening apparatus and plaster used in primary fixation.

osteosynthesis as the principal method of treatment of congenital pseudarthrosis,—the inlay graft of Albee, the massive onlay graft of Campbell, Henderson, Gill, and others, the plated osteoperiosteal graft of McBride, multiple chip grafts [17], whole fibular transplantation, proposed by Hahn[8, 20], and side-to-side tibiofibular synostosis. Orell, in 1937, contributed three types of heterogenous and homogenous grafts,—namely, os purum, os novum, and boiled bone. In 1941, Boyd reported the dual onlay graft (homogenous). Boyd excised the connective tissue forming the pseudarthrosis, then bridged the defect on the medial and lateral aspects by heavy homogenous grafts, transfixing the tibial fragments and grafts by Vitallium screws, of which two were placed proximally and two distally. The interval between the grafts was filled with chips.

Barney Brooks reported in 1920 the results of a series of experiments on dogs in which a bone graft was partially prepared, the wound was closed, and the graft was removed ten days later. Alizarin red was injected in order to stain the new bone which was formed. A total of seventeen experiments led Brooks to conclude that the os novum type of graft was more osteogenetic than the direct transplant, particularly in growing bone. Experimental work, reported in earlier publications, substantiated his conclusions.

In spite of the great advances made in bone-graft surgery since 1900, the results in congenital pseudarthrosis have been extremely discouraging. Mercer stated that Putti, in thirteen cases, had two recoveries. Nové-Josserand reported seven cases with three recoveries. Froelich had four cases with two failures; Campbell, in 1939, saw three cases, of which two were failures; Boyd, in 1941, reported six cases, with two failures.

FIG. 2-A

Fig. 2-A: A. E. Lateral and anteroposterior roentgenograms of the tibia and fibula show congenital pseudarthrosis. Note refracture through dual onlay graft. Three delayed graft procedures were necessary because of two spontaneous fractures. Fig. 2-B shows present status.

FIG. 2-B

Fig. 2-B: Anteroposterior and lateral roentgenograms show tibia and fibula one year after delayed graft. Note restoration of continuity of tibia and fibula, and of medullary cavity.

CLASSIFICATION OF PSEUDARTHROSIS

The outlook for the successful treatment of congenital pseudarthrosis would be extremely grave, were it not for the fact that bone continuity can be successfully restored through bone-grafting. Bone-grafting has for its primary purpose the stimulation of osteogenesis. It is obvious from the foregoing historical review that osteogenesis has been restored in many instances, with restoration of the skeletal defect and return of function. One might theorize that the end product of osteogenesis (laminated bone) in the pseudarthrosis area is defective in quality, in that it is not only incapable of withstanding the physiological stresses, but is equally incapable of repair. This is the author's working hypothesis, and is the basis for his classification of congenital pseudarthrosis into two principal types:

1. *Pre-pseudarthrosis:* In this stage the long bone is bowed or bowing, the apex of the bow is narrow, the medullary cavity becomes obliterated, and spontaneous or induced fracture (often surgical) occurs, followed by pseudarthrosis.

2. *Pseudarthrosis:* Various degrees may occur, from simple fibrous to frank nearthrosis, including sclerosis of the bone ends, cartilage, and joint cavity.

It is with this hypothesis in mind that the delayed autogenous bone graft is presented; it is an excellent means of producing osteogenesis.

THE DELAYED AUTOGENOUS BONE GRAFT

Preparation of the Graft

The delayed autogenous bone graft is a graft that is elevated from the tibia, fibula, or ilium, completely freed of all attachments, replaced in its natural bed, and, after routine closure, by layers, of the periosteum, subcutaneous tissue, and skin, is allowed to remain so imbedded for an average period of eighteen to twenty-one days. It is next removed subperiosteally, care being taken to preserve the new-bone attachment to its various surfaces. It is then implanted in the fragments comprising the pseudarthrosis.

Preparation of the Pseudarthrosis Site

Infection, if present, must be eliminated six months before grafting. Skin scars, adherent or wide, must be excised and healed one or two months before grafting.

The deep approach to the tibia or to the tibia and fibula should be made through the anterior compartment of the leg. The pseudarthrosis should be excised completely, including all fibrous tissue and the sclerosed bone ends. The tibial and fibular fragments should be aligned perfectly and then held in position; each is transfixed by two heavy Kirschner wires. All of the wires should be in the same plane, approximately one inch apart, and placed well away from the exposed ends of the tibial fragments. Care should be taken to avoid the epiphyseal lines. The author usually employs the Abbott bone-lengthening apparatus for directing the pins and holding the fragments while the graft is being inserted. One of the two lower pins occasionally has to be inserted into the calcaneus. The fibular fragments are fixed by an intramedullary Kirschner wire.

Implantation of Grafts

The tibial fragments are split as far as the nearest transfixion wire. The tibial graft is wedged at the ends and forced between the split surfaces of the proximal and distal tibial fragments. A smaller fibular graft is prepared, similar to the tibial graft; it is laid against the fibular fragments and fixed, if necessary, with a fine wire suture above and below. As previously stated, both the tibia and fibula are approached through the anterior muscle compartment. This necessitates retracting the muscles, vessels, and nerves away from each bone, in order to gain proper exposure. A single skin incision suffices for the exposure of both bones.

FIG. 3-A

Fig. 3-A: P. B. Anteroposterior and lateral roentgenograms, taken July 7, 1943, show congenital pseudarthrosis of the lower third of tibia and fibula. Note fracture through dual onlay graft.

FIG. 3-B

Fig. 3-B: Anteroposterior and lateral roentgenograms of tibia and fibula show restoration of continuity of both tibia and fibula, one year after delayed graft. Note bowing. This must be watched carefully, and new bone must be added if evidence of weakening appears.

FIG. 4-A

Fig. 4-A: L. C. Anteroposterior and lateral views of the right tibia show congenital pseudarthrosis.

Fig. 4-B: Anteroposterior and lateral views of the right tibia, twenty-two months after delayed bone graft.

FIG. 4-B

The wound is closed in layers, including the two incisions in the compartment employed for the tibia and fibula, the incision in the anterior wall of the compartment, and

FIG. 5-A

FIG. 5-B

Fig. 5-A: G. J. Anteroposterior and lateral roentgenograms of lower third of the left tibia, April 18, 1946.

Fig. 5-B: Anteroposterior and lateral views, October 16, 1947, eighteen months after delayed graft. Note restoration of continuity of both tibia and fibula; medullary cavity has been restored. Slight anterior and medial bowing persists and, if progressive, grafting will be necessary (subperiosteal grafts).

FIG. 6-A

FIG. 6-B

Fig. 6-A: F. M. Anteroposterior and lateral roentgenograms, taken April 8, 1947, show congenital pseudarthrosis of left ulna.

Fig. 6-B: Anteroposterior and lateral roentgenograms, eight months after delayed bone graft. Note restoration of continuity of medullary cavity. Ulna not growing as rapidly as radius. Radial bowing was corrected, prior to delayed graft, by delayed osteotomy. Radial growth arrest is indicated. Pin in lower portion of ulna represents method of fixation employed to attach delayed graft to distal ulnar epiphysis.

finally, the subcutaneous tissue and skin. Immediately before closure, the tourniquet is removed and complete hemostasis is obtained. Routine light dressings are followed by a plaster cylinder, including pins, which extends from toes to groin.

FIG. 6-C

Photomicrograph (× approximately 125) of bone graft, initial stage. This section shows adult laminated bone with viable lacunae cells.

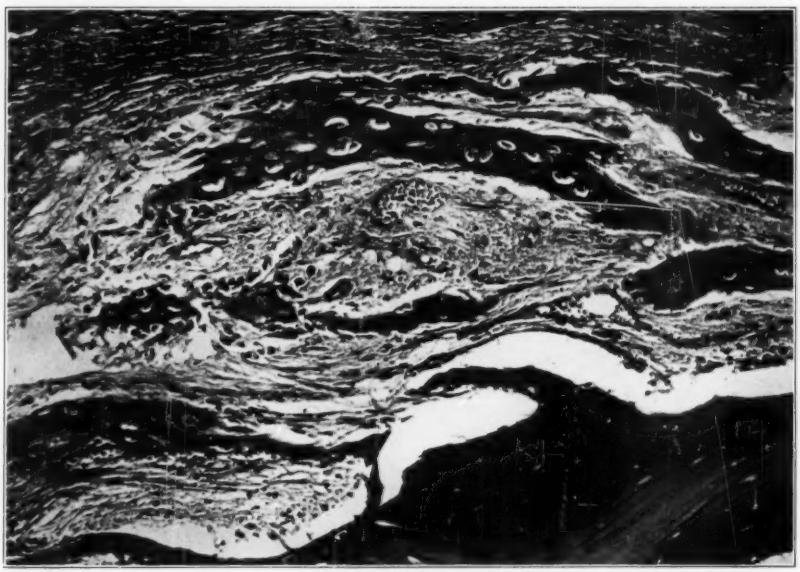

FIG. 6-D

Photomicrograph (× approximately 125) of bone graft, second or delayed stage. In one portion of the section there is a piece of adult bone which is now dead. Note the empty lacunae arising from this new-bone formation with osteoblastic activity and primitive bone spicules.

If leg-lengthening is to be performed, the pseudarthrosis is excised and the apparatus for lengthening is applied. The lengthening should be done very slowly,—one-sixteenth of

FIG. 7-A

FIG. 7-B

Fig. 7-A: J. S. Roentgenograms, taken October 24, 1946, following congenital pseudarthrosis in the upper third of the right tibia.

Fig. 7-B: Anteroposterior and lateral views of the right tibia, nine months after delayed graft. Note continuity; restoration of the medullary cavity nearly complete. Mild posterior bowing must be carefully watched and regrafting must be done, if necessary (subperiosteal graft on the concave side of the bow).

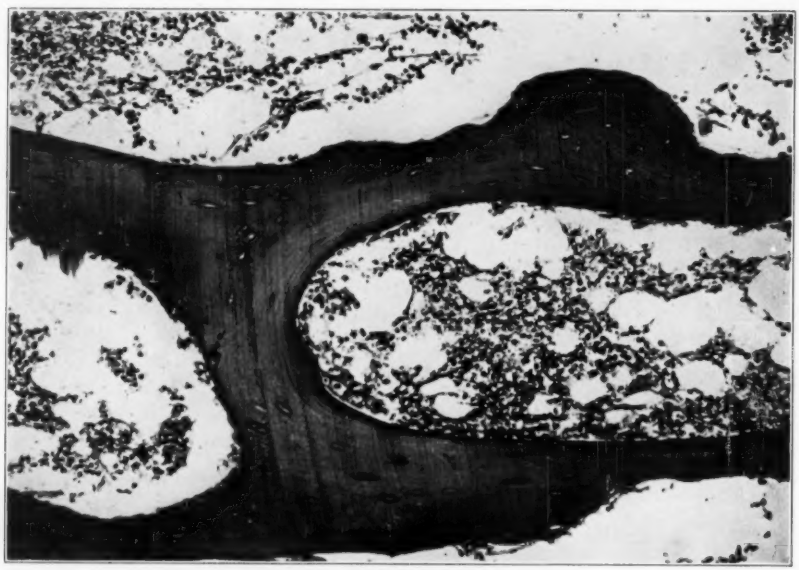

FIG. 8-A

C. K. Photomicrograph (× approximately 125) of bone graft, initial stage. Section shows normal adult bone, the viability of which is demonstrated by the presence of osteoblasts and lacunae.

an inch daily, beginning on the seventh day. The maximum length obtained in the present series was three and one-half inches. *The delayed graft must not be started until lengthening is complete and the operative wound has healed.* The first and second stages of the delayed graft, and the lengthening apparatus and plaster used in primary fixation, are shown in Figure 1. For a pseudarthrosis of the ulna, femur, or clavicle, delayed onlay grafts are used, and fixation is obtained by an intramedullary Steinmann pin or a Kirschner wire and Vitallium screws.

After-Treatment

The pins and plaster are maintained until the medullary cavity appears in the graft, which requires an average period of four to six months. A double-bar caliper brace, extending from ankle to groin, is then applied. This brace has a pelvic band and a full-length tibial leather cuff; a removable celluloid tibial cylinder is employed inside the cuff, but not attached to it. The brace is worn for two years.

Pertinent Points in the Technique

1. The bone grafts must overlap the fragments for two inches or more.
2. Fixation with four pins is essential.
3. The graft is held in position until a well-defined medullary cavity has appeared.
4. The application of the graft should not be delayed more than eighteen days in small children, or the graft will lose its identity.

CLINICAL AND LABORATORY DATA

Eight patients with congenital pseudarthrosis are presented; five are females and three are males. At the time of the delayed graft, two of the patients were four years of age, one

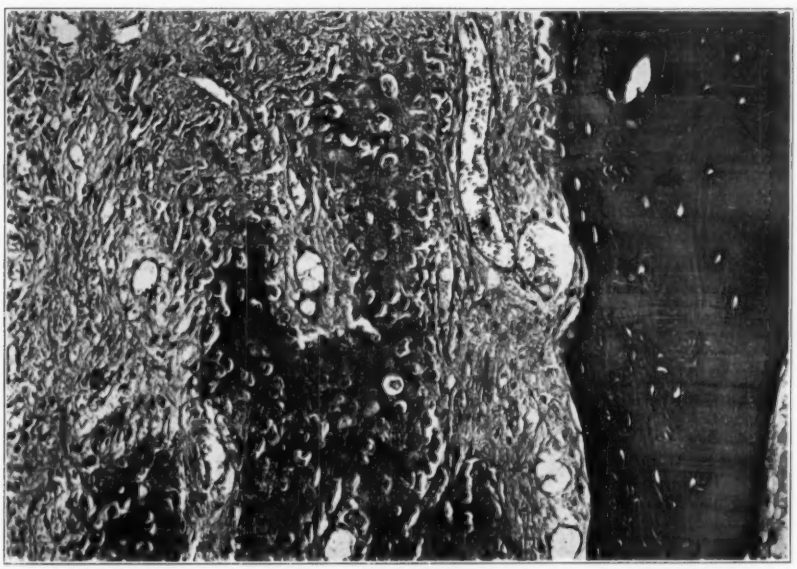

FIG. 8-B

Photomicrograph (× approximately 125) of bone graft, second stage or delayed graft. In one corner there is a piece of adult bone which is dead. Arising from this is new-bone formation in callus. Note the osteoblastic activity.

FIG. 9

C. M. Photomicrograph shows a representative area through the soft tissue, interposed between the ends of bone. The arrangement is not disorganized, as in tumor; and the nuclei are quite adult, showing none of the characteristics of neoplasia.

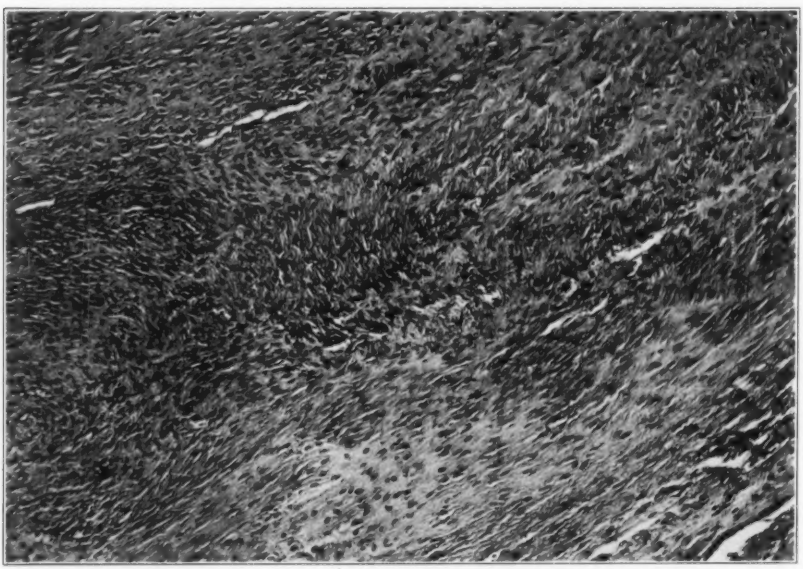

FIG. 10

E. R. Photomicrograph of soft tissue, interposed between the ends of fractured bone. There is marked fibroblastic hyperplasia with production of collagen bands. The cells are arranged in organized trabeculae, with a pattern suggesting that of attempted callus formation rather than neoplasia. Bone formation is lacking.

FIG. 11-A

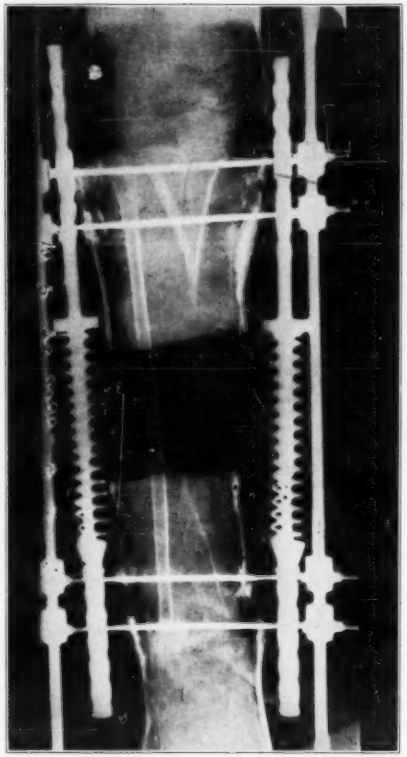

FIG. 11-B

FIG. 11-C

Fig. 11-A: M. J. J. Anteroposterior roentgenogram of the right tibia, showing the pseudarthrosis and massive bone defect secondary to osteomyelitis.

Fig. 11-B: Anteroposterior view, taken October 16, 1942, shows the effect of leg lengthening (three and one-half inches of lengthening), preliminary to the delayed graft.

Fig. 11-C: Anteroposterior and lateral roentgenograms of the tibia and fibula, four years after delayed graft. Note alignment, restoration of medullary cavity, and enlargement of tibia.

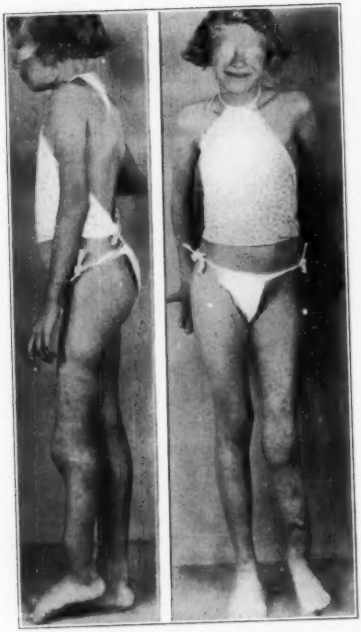

FIG. 12-A

FIG. 12-B

FIG. 12-C

FIG. 12-D

Fig. 12-A: R. G. Anteroposterior and lateral photographs, taken January 26, 1942, show typical congenital pseudarthrosis. Note café-au-lait spots, scarring from previous operations, and shortening.

Fig. 12-B: Anteroposterior and lateral roentgenograms show typical congenital pseudarthrosis of lower third of the tibia and fibula on the left.

Figs. 12-C and 12-D: Anteroposterior and lateral roentgenograms of the tibiae and fibulae of both right and left legs. Left tibia shows restoration and continuity of medullary cavity, six years after delayed graft. Lower end of tibia shows a sclerosis, representing the site of correction of the anterior bowing. Correction obtained by delayed osteotomy. The opposite tibia shows the leg-shortening procedure, after nine months.

was six, one seven, two eight, and two twelve. Patients A. E. and P. B. had three applications of the delayed graft, due to spontaneous fractures (Figs. 2-A, 2-B, 3-A, and 3-B). L. C. had additional small shaving grafts, in order to increase the diameter of the graft of the tibia (Figs. 4-A and 4-B).

The average period required before formation of the medullary cavity was six months. Café-au-lait spots were present in seven of the eight cases. Neurofibromata were present in two, G. J. (Figs. 5-A and 5-B) and E. M. In six cases the tibia and fibula were involved; in one case, the femur; and in one case, the ulna. F. M., the patient with pseudarthrosis of the ulna, had a deformed elbow at birth (Figs. 6-A and 6-B). D. M., the patient with involvement of the femur, presented a short lower extremity with thickening of the proximal portion of the thigh. In all cases of tibial and fibular pseudarthrosis, bowings were present at birth and fractures occurred during the first year. Heredity played no noticeable part. J. S. (Figs. 7-A and 7-B) had a brother with pre-pseudarthrosis.

Microscopic studies of material taken from the pseudarthrosis areas revealed mainly hyperplasia of fibrous tissue. A pathologist's report stated: "There is a mass of adult fibrous tissue in which there is collagen production. The interspersed fibrocytes are for the most part adult in type. There is no frank neoplastic proliferation here." *

TABLE I

ALKALINE-PHOSPHATASE DETERMINATIONS

Patient	First-Stage Graft (*Bodansky Units*)	Second-Stage Graft (*Bodansky Units*)	Increase or Decrease (*Bodansky Units*)
J. S.	88	178	+ 90
G. J.	75	180	+105
P. B.	520	662	+142
D. M.	540	320	−220
F. M.	Tests unsuccessful		

In J. S. and G. J., neurofibromata were found in microscopic sections of subcutaneous tumors. The blood calcium, phosphorus, and phosphatase were normal. Other laboratory studies, including Wassermann reactions, were negative. Microscopic sections of the first-stage bone graft showed normal bone. Microscopic sections of the bone graft at the second stage (after eighteen to twenty-one days) revealed the following: "The sections of the delayed bone graft show dead bone of the adult type, from the surface of which there is callus growth with provisional bone formation. Diagnosis: Delayed bone graft with new-bone formation." *

Alkaline-phosphatase determinations were performed on the grafts at the first and second stages in five of the cases (Table I).

Figures 6-C, 6-D, 8-A, and 8-B illustrate the microscopic sections of the delayed grafts; Figures 9 and 10, of the usual soft pseudarthrosis tissue.

Figures 11-A, 11-B, and 11-C show the tibia of M. J. J., before and after application of the delayed bone graft. This nine-year-old patient did not have congenital pseudarthrosis, but a pseudarthrosis due to osteomyelitis. Three and one-half inches of lengthening was obtained. This was the first case of pseudarthrosis in which the delayed autogenous

* Reported by E. E. Aegerter, M.D., Professor of Pathology, Temple University Medical School.

FIG. 13-A

M. M. Anteroposterior roentgenogram, taken January 11, 1947, shows congenital pseudarthrosis of the upper third of the right femur.

FIG. 13-B

Anteroposterior and lateral roentgenograms, taken September 3, 1947, show restoration of medullary cavity and continuity, eight months following delayed graft. Considerable bowing is present. The condition must be watched and, if progressive, regrafting should be done (subperiosteal graft).

graft was employed. Furthermore, the delayed graft bridged a six-inch defect, three and one-half inches of which had been produced by the leg-lengthening. Success in this case led to the use of the delayed graft in eight cases of congenital pseudarthrosis, as illustrated in Figures 2-A to 7-B and 11-A to 13-B, inclusive.

RESULTS

Successful osteosynthesis has been accomplished in eight cases of congenital pseudarthrosis. In six of these cases the deformity was in the leg; once it was in the ulna, and once in the femur. In five cases the period of follow-up ranged from eight months to a year; in the other three cases it was eighteen months, twenty-two months, and four years, respectively. In two cases, three delayed grafts were required; and in one case an additional bone was required for thickening, to prevent possible breaking. In one case a delayed osteotomy was performed through the healed pseudarthrosis area, to correct severe anterior bowing. In the pseudarthrosis of the tibia with a six-inch bone defect, restoration of the defect was accomplished by the delayed autogenous graft. In two cases spontaneous fracture occurred; and traumatic fracture occurred once in each of these cases, necessitating the extra grafting mentioned previously. Anterior bowing occurred in each of the cases of spontaneous fracture, and simulated the bowing seen in pre-pseudarthrosis. Grafting the fibula, better bracing, and improved after-care might have solved this problem.

CONCLUSIONS

The delayed autogenous bone graft is capable of stimulating osteogenesis. The extra supply of alkaline phosphatase and the attached newly formed bone may contribute to osteogenesis. Bony union occurred in each instance. The principal problem is one of meticulously nurturing the young bone until it can withstand the physiological forces and, later, the functional demand. Reinforcement of the newly formed tibia at its weak point, as evidenced by narrowing or incipient bowing, is imperative. Osteosynthesis of the fibula is believed to be of great value, not only in offering additional strength to the young tibia, but also in maintaining axial alignment. The importance of the continuation of primary immobilization until the medullary cavity has been formed, cannot be overemphasized. It offers the only criterion for the discontinuation of primary immobilization, by means of four pins and plaster fixation. A bimonthly roentgenographic check-up is essential during the first two years.

The follow-up period in all of the cases is probably too short to justify final conclusions. The fact that union occurred in every case in which the delayed graft was used, including those cases in which re-operation was done, is distinctly encouraging, and points to the effectiveness of this type of graft. In L. C., bending started at a narrowed point in the tibial graft, but prompt reinforcement with cortical grafts (not delayed grafts), at the site of the apparent weakness, prevented spontaneous fracture and brought about proper restoration. In the two cases in which spontaneous fracture occurred, it could probably have been avoided, had early bending been detected and the area been reinforced. In addition, if the policy of reinforcement were employed early—that is, when the graft became narrowed or at the time of the incipient bending—the danger of spontaneous fracture would be reduced.

The treatment of congenital pseudarthrosis will probably never be entirely effective until the etiology has been determined. Osteosynthesis by bone-grafting still offers the principal means of attacking the problem. It is the author's belief that improvements in surgery, in bone-grafting, in bone-graft material, and in fixation, protection during the follow-up period, and early reinforcement of weak grafts will offer greater hope of successful treatment and will reduce the number of failures and amputations.

NOTE: Translations of French and Italian articles were made by Miss Mary Vanderhoof, through the courtesy of George E. Bennett, M.D.

REFERENCES

1. Albee, F. H.: Orthopedic and Reconstruction Surgery. Industrial and Civilian, p. 150. Philadelphia, W. B. Saunders Co., 1919.
2. Barber, C. G.: Congenital Bowing and Pseudarthrosis of the Lower Leg. Manifestations of von Recklinghausen's Neurofibromatosis. Surg., Gynec., and Obstet., **69**: 618–626, 1939.
3. Bocchi, Luigi: Angiografia in un caso di pseudoartrosi congenita della tibia. Chir. d. Org. di Movimento, **23**: 154–160, 1937.
4. Boyd, H. B.: Congenital Pseudarthrosis. Treatment by Dual Bone Grafts. J. Bone and Joint Surg., **23**: 497–515, July 1941.
5. Brooks, Barney: Studies in Regeneration and Growth of Bone. The Demonstration of New Formed Bone by Intravital Staining. Ann. Surg., **65**: 704–710, 1917.
6. Brooks, Barney: Studies in Bone Transplantation; A Study of a Method of Increasing the Osteogenetic Power of a Free Bone Transplant. Ann. Surg., **69**: 113–126, 1919.
7. Brooks, Barney: A New Method of Bone Transplantation. Southwest. J. Med. and Surg., **28**: 59–60, 1920.
8. Campbell, W. C.: Operative Orthopedics, pp. 716–723. St. Louis, C. V. Mosby Co., 1939.
9. Camurati, Mario: Le pseudoartrosi congenite della tibia. Chir. d. Org. di Movimento, **15**: 1–162, 1930.
10. Codivilla, A.: On the Cure of the Congenital Pseudarthrosis of the Tibia by Means of Periosteal Transplantation. Am. J. Orthop. Surg., **4**: 163–169, Oct. 1906.
11. Codivilla, A.: Sulla cura della pseudo-artrosi congenita della tibia. Arch. di Ortop., **24**: 215–232, 1907.
12. Coenen, Hermann: Zur plastischen Behandlung der Unterschenkelpseudarthrosen. Arch. f. Klin. Chir., **83**: 1011–1031, 1907.
13. Ducroquet, Robert: A propos des pseudarthroses et inflexions congénitales du tibia. Mém. Acad. de Chir., **63**: 863–868, 1937.
14. Froelich: Traitement des pseudarthroses congénitales. Rev. d'Orthop., **1** (3 Série): 1–19, 1910.
15. Gill, A. B.: Treatment of Ununited Fractures of the Bones of the Forearm. Surg. Clin. North America, **12**: 1535–1544, 1932.
16. Green, W. T., and Rudo, Nathan: Pseudarthrosis and Neurofibromatosis. Arch. Surg., **46**: 639–651, 1943.
17. Hallock, Halford: The Use of Multiple Small Bone Transplants in the Treatment of Pseudarthrosis of the Tibia of Congenital Origin or Following Osteotomy for the Correction of Congenital Deformity. J. Bone and Joint Surg., **20**: 648–660, July 1938.
18. Henderson, M. S.: The Massive Bone Graft in Ununited Fractures. J. Am. Med. Assn., **107**: 1104–1106, 1936.
19. Horwitz, Thomas, and Lambert, R. G.: Treatment of Ununited Fractures of Long Bones. A Method Combining Grafting and Internal Fixation. J. Bone and Joint Surg., **27**: 637–644, Oct. 1945.
20. Huntington, T. W.: Case of Bone Transference. Use of a Segment of Fibula to Supply a Defect in the Tibia. Ann. Surg., **41**: 249–251, 1905.
21. Ker, Thomas: A Case of Fracture of the Bone of the Under Jaw, Successfully Treated by Dr. Physick, with a Seton. Philadelphia J. Med. and Phys. Sciences, **5**: 116–118, 1822.
22. Lindemann, K.: Die Pathogenese der angeborenen Unterschenkelpseudarthrose. Ztschr. f. Orthop., **74**: 256, 1943.
23. Lombard, Pierre; Verain; Royer; et Couillaud: Note sur l'état physique du tissu osseux dans la pseudarthrose congénitale du tibia. Mém. Acad. de Chir., **71**: 180–181, 1945.
24. McBride, E. D.: Plated Osteoperiosteal Graft. J. Am. Med. Assn., **121**: 652–655, 1943.
25. Malkin, S. A. S.: Congenital Pseudarthrosis of the Tibia Treated by Twin Grafts. Proc. Royal Soc. Med., **38**: 71–74, 1944.
26. Mercer, Walter: Orthopaedic Surgery, Ed. 3, p. 43. Baltimore, Williams and Wilkins Co., 1943.
27. Moore, B. H.: Some Orthopaedic Relationships of Neurofibromatosis. J. Bone and Joint Surg., **23**: 109–140, Jan. 1941.
28. Moore, J. R.: Pseudoarthrosis of the Tibia and Fibula in Children. J. Internat. Coll. Surg., **9**: 7–13, 1946.
29. Moore, J. R.: Osteotomy-Osteoclasis. J. Bone and Joint Surg., **29**: 119–129, Jan. 1947.
30. Nové-Josserand: Pseudarthrose congénitale de la jambe guérie par la transplantation d'un lambeau ostéo-périosteo-cutané pédiculé pris dans la jambe saine. Lyon Méd., **111**: 920–923, 1908.
31. Orell, Svante: Surgical Bone Grafting with "Os Purum", "Os Novum", and "Boiled Bone". J. Bone and Joint Surg., **19**: 873–885, Oct. 1937.
32. Reichel, P.: Zur Behandlung schwerer Formen von Pseudarthrosis. Ein Beitrag zur Behandlung der sog. intrauterinen Fracturen des Unterschenkels. Arch. f. Klin. Chir., **71**: 639–651, 1903.
33. Tillier, R.: Courbures et pseudarthroses congénitales de la jambe. Rev. d'Orthop., **15** (3 Série): 97–116, 1928.

DISCUSSION

Dr. William T. Green, Boston, Massachusetts: Dr. Moore's contribution is one of major importance. Congenital pseudarthrosis of the tibia and fibula is one of the most difficult conditions in which to

obtain osseous union, at least in early childhood. The results that he has shown, which I assume represent consecutive cases, are far better than have been obtained in any other series of which I am aware.

Some of the factors that may enter into the results which he has obtained are:

1. The technique of delayed bone-grafting.
2. The use of the lengthening apparatus to immobilize, and to obtain length where necessary.
3. The thorough excision of interposed soft tissue and of the abnormal bone at the site of the defect.
4. The use of a graft long enough to extend well across the site of non-union into good bone.
5. The use of a graft for the fibula as well as for the tibia.
6. The strengthening of the area by additional grafts, when necessary, before fracture occurs.

Of these technical points, the one which we have not used and the one which I believe is of great importance is that of the delayed bone graft. That represents an evolutionary step from the work of Orell, who implanted beef bone, especially prepared so as to remove the organic material, into the front of the tibia. This beef bone, which he called "os purum", stimulated the formation of new bone, which he appropriately called "os novum". He then transplanted this os novum, either with or without the os purum. Dr. Moore has produced his os novum in another way, with the additional advantage that the rest of the graft is not beef bone, but autogenous bone of a mass which gives stability.

In the transplantation of bone, only those cells immediately in relation with tissue fluids survive. In Dr. Moore's technique, the graft is left *in situ* long enough for the proliferation of new bone which, when transferred, should preserve its viability. Whether or not it does, could and should be substantiated experimentally.

Dr. Moore has given his technique a rigorous test in the problem of pseudarthrosis, and the results have been excellent. The question arises immediately as to whether the technique should not be used widely in other conditions. The objection which might be raised is that its use requires an additional operation and a period of disability, preliminary to the transplantation of the bone. However, the incidence of non-union after bone-grafting is frequent enough, particularly in certain conditions, so that I feel the value of the method must be explored in a wider range of uses. The short additional time necessary at the start in this technique is certainly worth while if it diminishes the percentage of non-union and shortens the period of disability after the transplantation.

It does not seem appropriate to discuss the relation of neurofibromatosis to pseudarthrosis, since this will only detract from the emphasis I would like to place upon the technique which has been described. This was an excellent paper; time will determine its full significance.

Granting that Brooks described a similar delayed graft some years ago, it has not lived as a working procedure.

DR. DALLAS B. PHEMISTER, CHICAGO, ILLINOIS: The successful healing obtained in such a high percentage of cases is evidence of the merit of the procedure employed by Dr. Moore. It is necessary to evaluate both the mechanical and the biological principles involved in order to decide their relative roles in the success of the operation.

The mechanical principles all seem to be sound and, since they were well applied, were undoubtedly of great importance.

From the biological standpoint, the fracture occurs through a segment of the tibia, and perhaps also of the fibula, which is the seat of congenital local imperfect osteogenesis. Removal of the defective and often extensively absorbed segment, by excision of the fragment ends and replacement by an autogenous graft from healthy bone, has points in its favor, although addition of the onlay graft, with as much as possible of the fragment ends preserved, helps to maintain a larger volume of bone and has long been used with success. Sometimes the fragments are fairly well preserved at the fracture level, in which case the question arises of whether an ample onlay graft may not work as well as complete substitution. When the delayed graft is used, callus forms along its periosteal and endosteal surfaces from surviving unossified osteogenic cells, during the three-week period between the cutting and the transference; this is partly fibrous and partly spongy bone. This callus participates in the establishment of union, and the subsequent creeping replacement of the necrotic cortex of the graft by new bone. After transplantation, more unossified osteogenic cells may survive in this callus than in the periosteum and endosteum of a fresh transplant. The procedure looks promising, but perhaps more control operations should be performed, the same mechanical procedure being used, but with freshly cut grafts.

DR. CHARLES W. PEABODY, DETROIT, MICHIGAN: The Spanish surgeon, Dr. Trueta, who since 1939 has been an active surgeon on the staff of the Wingfield Morris Hospital at Oxford, England, is now traveling in this country, and I was recently favored by a visit from him. He mentioned some recent experiences with the problem of pseudarthrosis, and Dr. Moore's illustration of prolonged skeletal fixation may make pertinent the mention of Dr. Trueta's conclusion.

Dr. Trueta reported that his last four cases had been cured by the use of the Küntscher intramedullary

(*Continued on page 66*)

APPROACH TO AND EXPOSURE OF THE HIP JOINT FOR MOLD ARTHROPLASTY

BY M. N. SMITH-PETERSEN, M.D., BOSTON, MASSACHUSETTS

A joint has two surfaces which must be so shaped as to be able to function without interference or impingement through the greatest possible arc. Consequently, in the case of the hip joint, it is necessary to expose the acetabulum and its adjacent structures, as well as the femoral head and neck. In the past the various approaches to the hip joint have failed to properly expose the acetabulum, and the surgeon's efforts have been directed mainly at partial reconstruction of the femoral head. Reconstruction of the acetabulum demands intrapelvic exposure of this side of the joint. The approach to such an exposure necessitates extensive dissection; since this can be carried out along structural planes, it is not destructive (Figs. 1 and 2).

The skin incision extends from the junction of the middle and anterior thirds of the iliac crest to the anterior superior spine, deviating slightly laterally along the medial border of the tensor fasciae latae (Fig. 3).

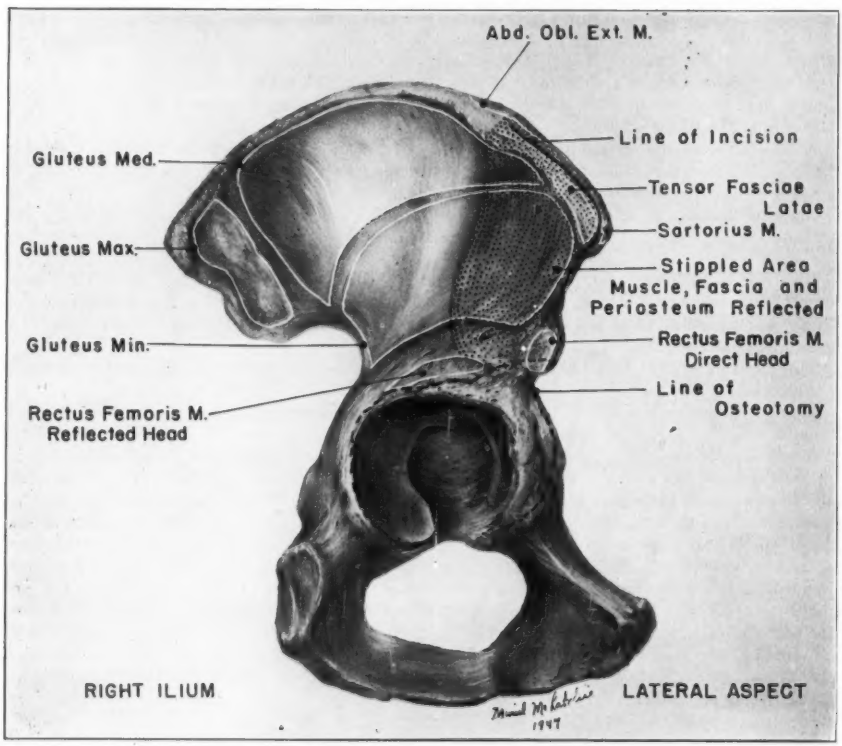

FIG. 1

Lateral aspect of ilium.

The purpose of this diagram is to demonstrate the extent of the osteotomy and reconstruction of the acetabulum necessary for mold arthroplasty.

The dotted line represents the line of osteotomy; the stippled area represents the extent to which the periosteal muscular attachments must be reflected.

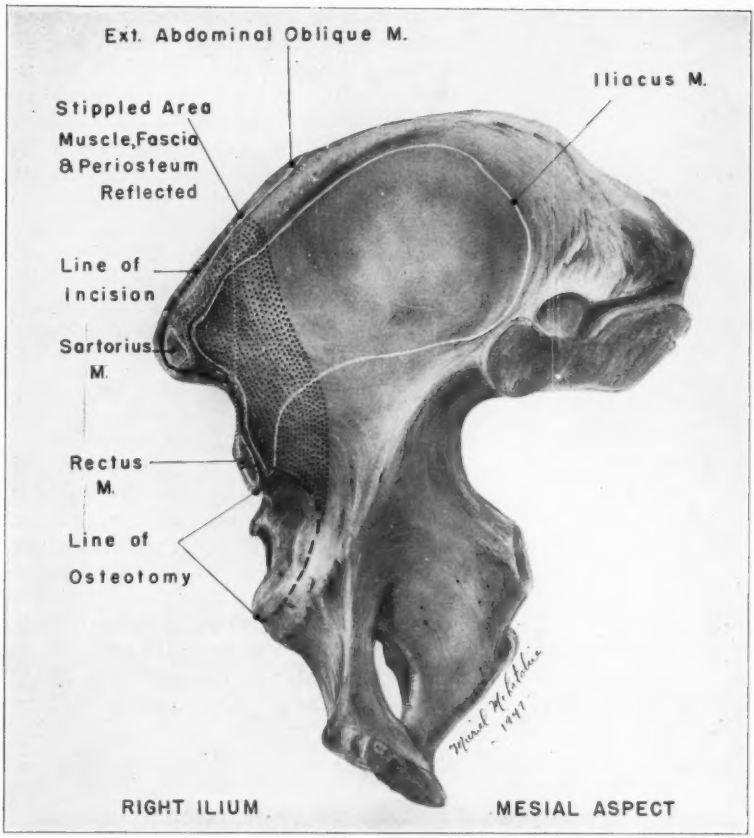

FIG. 2

Medial aspect of ilium.

The purpose of this diagram is the same as that of the preceding one. It also shows the line of incision of the periosteum between the external abdominal oblique and the sartorius medially, and the glutaei and tensor fasciae latae laterally.

It should be noted that the osteotomy includes the inferior half of the anterior inferior iliac spine.

The superficial fat and fasciae are incised down to the deep fasciae covering the external abdominal oblique and gluteal muscles, superiorly, and the sartorius and tensor fasciae latae, inferiorly. Between the sartorius and the tensor fasciae latae is a fat compartment, covering the upper portion of the rectus femoris. By incision of the femoral fascia between the sartorius and the tensor fasciae latae, a plane of cleavage becomes apparent between the posterior surface of the sartorius and the anterior surface of the iliopsoas as it emerges from underneath Poupart's ligament. This plane of cleavage is easily developed by blunt dissection (Fig. 4).

Attention is now directed towards developing the superior portion of the approach. The plane of cleavage between the abdominal and gluteal fasciae is defined and an incision is made through the periosteum, down to bone. By periosteal reflection of the attachments of the abdominal muscles, sartorius, and Poupart's ligament, medially, and of the glutaeus medius, tensor fasciae latae, and glutaeus minimus, laterally, the anterior third of the ilium is exposed (Fig. 4).

FIG. 3
Skin incision.

Depending upon the character of the operation to be performed, the direction of the anterior limb of the incision may be varied. If the greater trochanter is to be transplanted, the incision must be extended laterally across the iliotibial band distal to the insertion of the tensor fasciae latae.

In order to expose the anterior capsule of the hip joint, the deep iliac fascia is divided between the main origin and the acetabular origin of the iliacus muscle. The motor fibers from the femoral nerve to the rectus femoris must always be exposed; they are surrounded by fat and lie on the anterior surface of the iliacus muscle, directly beneath the iliac fascia as this becomes confluent with the deep femoral fascia (Fig. 5).

The anterior inferior iliac spine has now been exposed. Attached to it we have the direct head of the rectus femoris muscle and the acetabular origin of the iliacus muscle, medially; laterally, the reflected head of the rectus is concealed in the supra-articular fat compartment.

All joints have periarticular fat compartments, the function of which is to facilitate the gliding mechanism close to the joint. In the case of the hip joint, we have such fat compartments medially, inferior to the origin of the iliacus from the iliac fossa, and laterally, between the superior aspect of the capsule and the inferior origin of the glutaeus minimus. Between the inferior capsule and the iliopsoas tendon is a similar fat compartment, containing articular branches from the lateral circumflex femoris artery.

It is important to define these fat compartments in order to expose the capsule with its ligaments. By retraction of the iliopsoas medially, the anterior and inferior portions of the capsule of the hip joint are exposed (Fig. 5). The rectus muscle and the acetabular

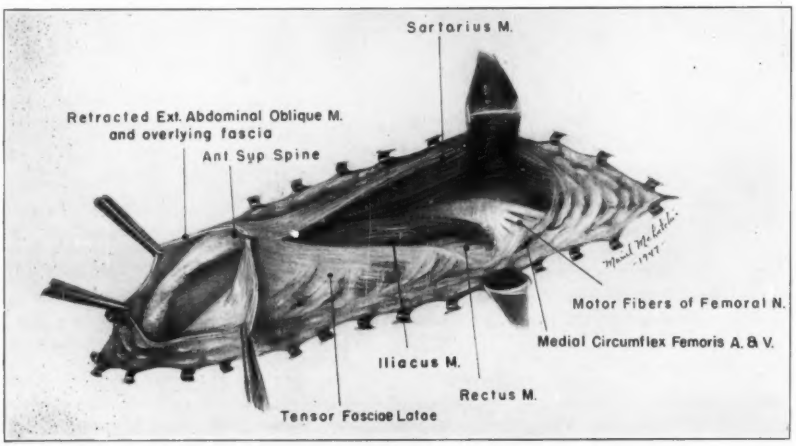

FIG. 4
Structural planes.

The anterior limb of the incision has been developed, exposing the iliacus with the overlying motor fibers of the femoral nerve. The tendinous structure of the rectus femoris is not shown, because it is embraced by the acetabular origin of the iliacus. Superiorly, the muscular periosteal attachments have been reflected from the medial and lateral surfaces of the ilium.

The sartorius is muscular at its origin; the tensor fasciae latae is tendinous. There is less tendency to fraying of the sartorius, if the line of division is carried through the tendinous portion of the tensor fasciae latae.

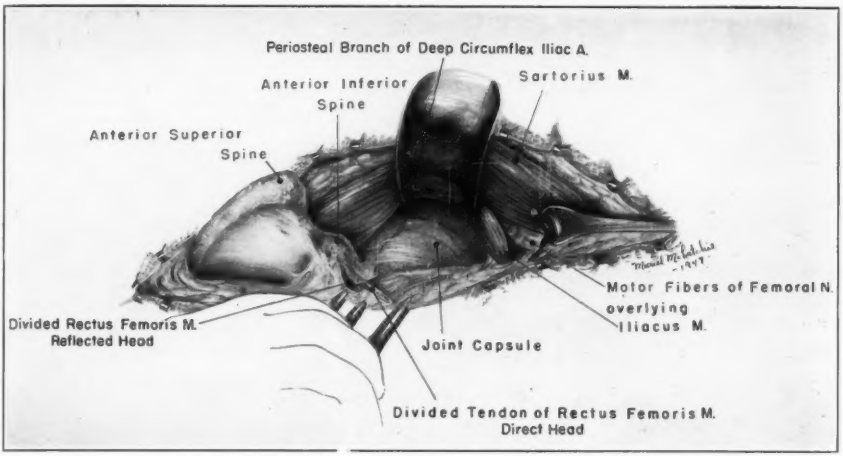
Periosteal Branch of Deep Circumflex Iliac A.
Anterior Inferior Spine
Sartorius M.
Anterior Superior Spine
Motor Fibers of Femoral N. overlying Iliacus M.
Divided Rectus Femoris M. Reflected Head
Joint Capsule
Divided Tendon of Rectus Femoris M. Direct Head

FIG. 5

Exposure of joint capsule.

Illustrations of surgical procedures are often inaccurate, sometimes actually misleading. The text states that the direct head of the rectus is divided and reflected laterally with the Y ligament and fibrous portion of the capsule. The diagram shows the rectus divided and retracted, the capsule remaining intact. This does occur when the structural planes are intact, but frequently the structures anterior to the joint capsule cannot be identified and then it is wise to include the fibrous capsule and the ligaments in the flap to be retracted laterally. In any and all cases, as complete a synovectomy as possible is carried out.

The indefinite area above the divided, reflected head of the rectus femoris represents a fat compartment. Nutrient arteries enter the ilium at this level, so it is better not to carry reflection of the periosteum below the origin of the glutaeus minimus; it is easier to put a snap on an artery in soft tissues than to plug a nutrient foramen. Soft-tissue dissection is carried out between the glutaeus minimus and the reflected head of the rectus, dividing all structures resisting dislocation.

The periosteal branch of the deep circumflex iliac artery can as a rule be identified, clamped, and tied. Inferior to the capsule and pubofemoral ligament is a fat compartment containing venous and arterial articular branches; these are easily controlled by diathermy. It is necessary to develop this compartment in order to be able to divide the capsule and ligaments completely; these structures are often contracted and resist dislocation. The iliopsoas tendon forms the floor of this compartment; it is a good guide to the lesser trochanter.

origin of the iliacus muscle are divided close to the anterior inferior iliac spine and reflected laterally with the limbs of the Y ligament of Bigelow and the fibrous portion of the joint capsule.

An osteotomy of the anterior inferior iliac spine and the anterior acetabular wall is now performed. Attached to this bony structure are remnants of the fibrous capsule and the synovial membrane; these are all excised with due respect for the distal attachment of the capsule, since this is the point of entrance of the circulation to the head and neck. By this procedure the acetabulum and the anterior aspect of the head and neck are exposed, rendering both sides of the joint available for complete reconstruction.

Arthroplasty of any type requires dislocation of the joint. In the case of the hip joint this step is often difficult. By sacrificing the inferior half of the inferior iliac spine and the anterior acetabular wall, before an attempt is made to dislocate the hip, this manoeuvre is greatly facilitated (Figs. 6 and 7). The extent and type of reconstruction of the joint varies according to the condition for which the operation is undertaken.

The purpose of the operation is to create a joint with approximately normal mechanics. This supplies the clue to the fitting of the mold. Normally, joint surfaces glide over one another with a minimum amount of friction; consequently, the mold must be loosely fitted so as to allow the greatest possible range of motion between it and the adjacent, reshaped surfaces of the femoral head and acetabulum (Fig. 8).

Before closure of the wound, it is advisable to try out the function of the joint as far as

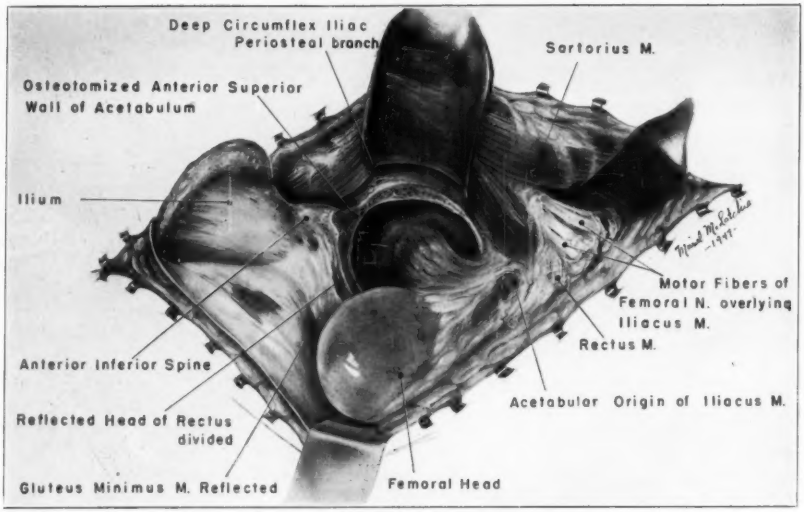

FIG. 6

Dislocation of the hip.

It is unwise to attempt to dislocate the hip without first doing at least a partial osteotomy of the acetabulum and excision of the anterior portion of the capsule. In some cases of malum coxae senilis, with large, deformed femoral heads and osteophytes along the articular margin, it is helpful to begin reshaping the head before dislocating the hip.

It is hardly necessary to point out the need of dividing the superior and inferior capsular structures completely.

This diagram shows an extreme displacement of the femoral head from the acetabulum. It is in the exceptional case only that such an exposure is obtained.

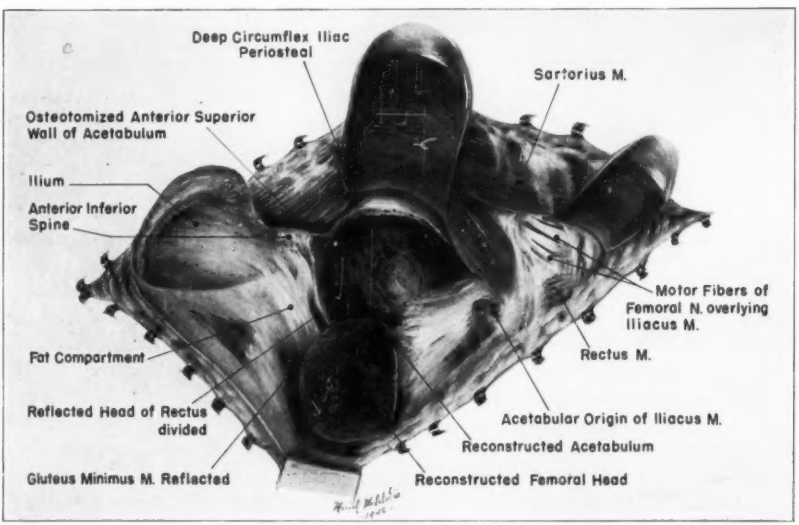

FIG. 7

Plastic procedure completed.

The femoral head and the acetabulum have been reconstructed. Their surfaces are smooth and congruous. "Congruous" is not exactly the right term, since the acetabulum should always be relatively large as compared with the femoral head. It might be better to say that the surfaces of the

Fig. 7 (*Continued*)

acetabulum and the femoral head represent segments of spheres of different diameters, one concave, the other convex.

The femoral head may be large, as in malum coxae senilis, or it may be small and deformed, and the femoral neck correspondingly short, as in congenital dislocation of the hip. In the majority of hip conditions, it is wise to create a joint space by sacrificing bone from the acetabular side and create "an acetabulum relatively large as compared with the femoral head".

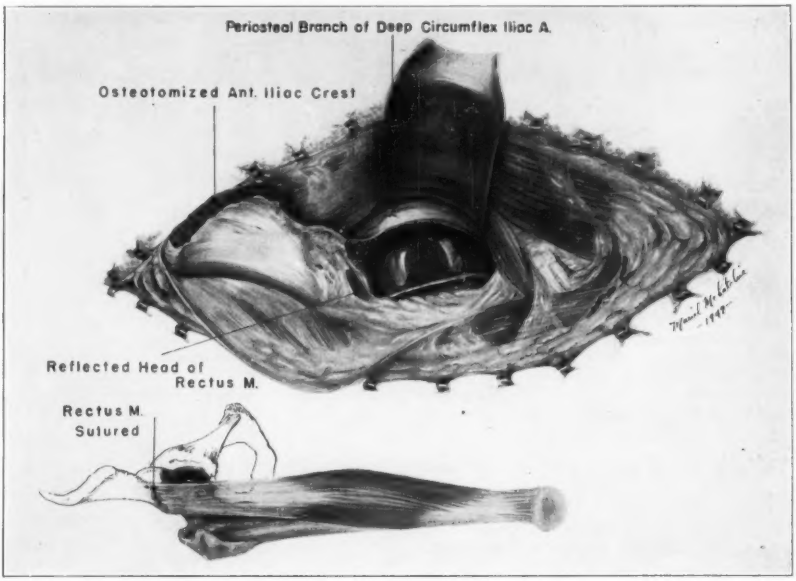

FIG. 8

Fitting the mold.

Physiological repair demands motion and a minimum amount of friction between the mold and the adjacent reconstructed joint surfaces. For this reason the mold should be freely movable in the acetabulum and fit loosely over the femoral head.

The mold should be deep enough to allow its edge to extend beyond the margins of the acetabulum. If at any point the edge is inside the acetabulum, new-bone formation will grip the edge and prevent freedom of motion of the mold. Since the normal hip is a ball-and-socket joint, all motions take place by rotation of one joint surface on the other. However, the normal hip is a simple ball-and-socket joint with only two surfaces, whereas the mold-arthroplasty joint is a compound ball-and-socket joint with four surfaces. The range of motion in such an artificial joint depends upon freedom of motion between all four joint surfaces. If the mobility between the mold and the acetabulum for some reason is restricted, it is important to compensate for it by freedom of motion between the femoral head and the mold. In order to obtain freedom of motion in flexion and extension, the femoral head and neck must be so shaped that they will have a tendency to a varus relationship to the mold. By this means, flexion and extension will take place by rotation of the femoral head inside the mold and will be independent of mobility of the mold inside the acetabulum. In congenital dislocation of the hip, there is invariably a varus relationship of the femoral head and neck to the shaft. Patients with this condition, almost without exception, obtain freedom of flexion and extension by arthroplasty.

Osteotomy of the anterior iliac crest is done in all cases. This allows suturing of abdominal to gluteal structures without tension.

range of motion and stability are concerned. This gives the surgeon information which enables him to decide upon the optimum postoperative position and to guide postoperative exercises intelligently.

The surgical procedure of arthroplasty necessarily creates cancellous bone surfaces. Such surfaces have a tendency to proliferate and create spurs or exostoses. In our experience, diathermy cauterization diminishes this tendency. We, therefore, cauterize the margins or edges of the new acetabulum,—that is, the anterior inferior iliac spine, the anterior

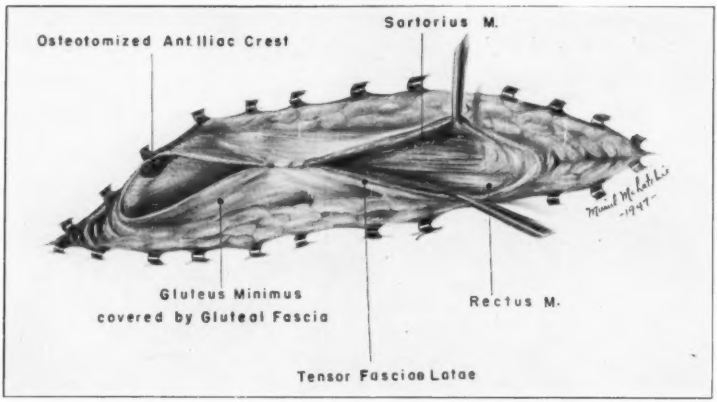

FIG. 9

Closure.

The divided tendon of the direct head of the rectus is sutured to the stump of the reflected head of the rectus. If the latter is not intact, the rectus is sutured to the central tendinous origin of the glutaeus minimus.

After osteotomy of the iliac crest, the wound is closed in layers. Since the approach follows structural planes, the closure presents no difficulty.

acetabular edge, the cotyloid notch, and the posterior capsular attachment to the acetabulum.

The closure of the wound is relatively simple, since the approach follows structural planes. The direct head of the rectus muscle is sutured to the reflected head, if this has been preserved; if not, it is sutured to the central tendon of the glutaeus minimus. By excision of the anterior superior iliac spine and crest, the abdominal muscles and fascia are sutured to the gluteal muscles and fascia without tension (Fig. 9). The deep and superficial fasciae are approximated in layers.

Because of uncontrollable oozing from cancellous bone surfaces, there is considerable loss of blood. Transfusions are, therefore, administered from the beginning of the operation in order to prevent serious shock.

AVASCULAR NECROSIS OF LARGE SEGMENTAL FRACTURE FRAGMENTS OF THE LONG BONES *

BY EDWARD L. COMPERE, M.D., CHICAGO, ILLINOIS

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Death of the head of the femur has resulted from intracapsular fracture of the femoral neck or from dislocation of the hip [9]. Aseptic necrosis of small bones, such as the tarsal or carpal navicular or lunate bone, and of epiphyses at the distal end of the metatarsals has been described [5]. These are the more commonly recognized locations for aseptic necrosis of bone following trauma. Death of the body of the talus, following fracture or fracture-dislocation, and death of large fragments in segmental fractures of the long bones have been described by Phemister [9, 10], but the clinical significance of traumatic devitalization of portions of the shafts of long bones has not been recognized by many fracture and orthopaedic surgeons.

Greenberg and Mohamed ligated the left femoral artery of rats. Both the right and left fibulae were then fractured. The fracture of the fibula in the leg in which the circulation had not been interfered with healed promptly. There was "a long delay in bone fracture healing" in the fibula of the leg in which the artery had been ligated. The breaking strength in the healing control bone was nearly twice as great at the end of twelve days as was that of the bone in the partially avascular extremity after twenty-four days. This

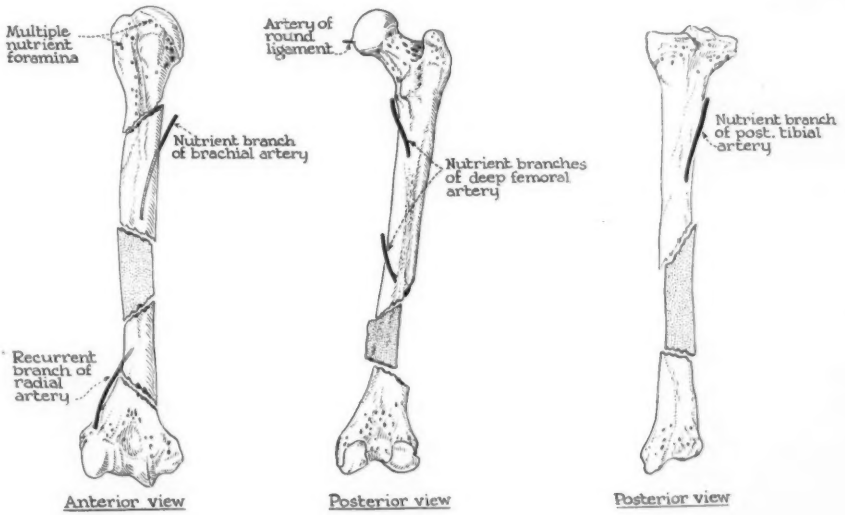

FIG. 1

Diagrammatic illustration of sources of blood supply to the more important long bones. Note that most long bones have only one principal nutrient artery, which is fairly constant with regard to the site of entry. Approximately one-half of the thickness of the outer cortex of the bone is nourished by the very small periosteal communicating vessels. A segment which is completely detached from the end fragments will retain very little blood supply, unless the nutrient artery is intact and supplies this fragment.

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

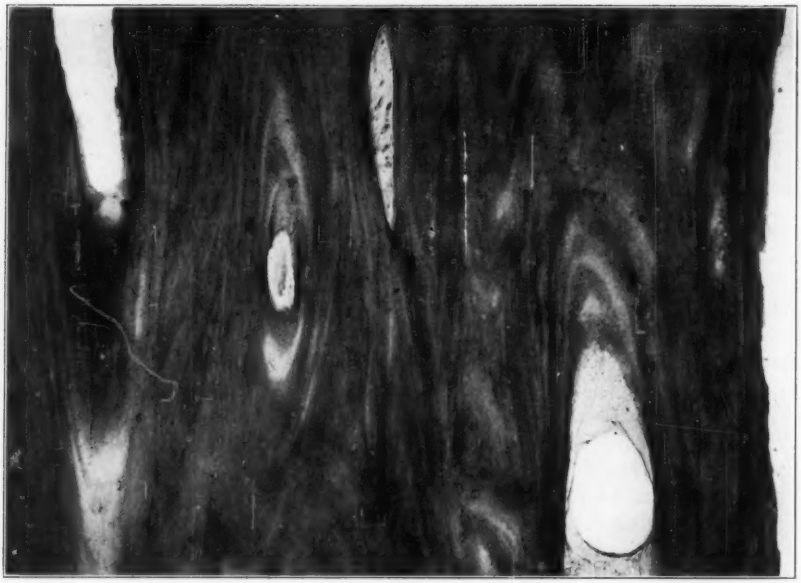

FIG. 2

Photomicrograph (× 100) of a microscopic section of a full-thickness tibial bone graft, obtained six months after transplantation for fracture of the humerus. The bone cells have disappeared, together with their nuclei, indicating death of the graft.

experiment does show that a marked decrease in blood supply to a bone will delay healing of a fracture.

Brunschwig, while in the Department of Surgery at the University of Chicago, produced aseptic necrosis in the tibiae and femora of young dogs by extensive separation of periosteum from the bone. This deprived the bone of nutrition from nutrient arteries and periosteal vessels. There was no massive sequestration, but the devitalized bone was replaced by creeping substitution. New bone formed from the adjacent living bone and from surviving osteogenetic elements of the separated bone and periosteum.

Johnson has studied the blood supply to the larger long bones. He found that the diaphyses of the bones are nourished by: (1) the nutrient artery, which penetrates the cortex of the shaft and branches to extend toward both ends of the bone; (2) the metaphyseal vessels, a branching network of small arterioles which penetrate the cancellous bone near the ends of the shaft and extend into the medullary tissue; and (3) the periosteal blood supply, which nourishes the outer half of the cortex and is least important of the three.

A large fragment in a comminuted fracture of the femur, tibia, humerus, or one of the bones of the forearm may be so detached from surrounding soft tissue that nutrient, metaphyseal, and periosteal blood vessels supplying the fragment are separated from it (Fig. 1). In such cases, the segmental fragment and sometimes the ends of the two major fragments are so devitalized that they are in the same situation as a full-thickness autogenous bone graft (Fig. 2). Axhausen and Bergmann showed that some bone cells attached to the periosteum and at least some endosteum of bone transplants survive and take active part in generating new bone. As is true of the bone graft, most of the bone cells of a large fracture fragment die. Active hyperaemia of adjacent bone and soft tissue follows the injury. Some peripheral or superficial bone cells survive. Other adjacent bone tissues become active. A vascular fibrous stroma invades the necrotic bone and aids in absorption.

There are large phagocytic cells which resorb dead marrow. This resorption by invasion of phagocytes and fibrous tissue is followed by bone formation. Both processes are going on at the same time. This transformation is very slow and may require years until new bone with Haversian canals and red bone marrow has replaced the old necrotic bone and the intervening callus (Fig. 3).

Phemister [9, 10] has most accurately described this method of bone absorption and replacement; he termed "creeping substitution" the process which Axhausen had previously called *schleichender Ersatz*. In all instances of aseptic necrosis, union of the fracture will be delayed and complete healing with recanalization must await replacement of devitalized bone by creeping substitution.

FIG. 3

Photomicrograph (× 50) of bone from the major fracture fragments of a humerus with non-union, six months after injury. The dead bone shown in this section is undergoing absorption and replacement by creeping substitution.

Phemister, in 1930, discussed aseptic necrosis following interference with blood supply in fractures of the neck of the femur, the body of the talus, the calcaneus, and in bone transplants. Cornil and Coudray reported as early as 1904 that, in experimental fractures, necrosis of the cortex is present for a variable distance from the fragment ends. This zone of necrosis is replaced slowly by bone growing in from the living cortex, with which it is continuous, and to some extent from the adjacent callus. The process of healing of a fracture takes place simultaneously with the transformation by creeping substitution of the necrotic bone to new living bone. Leriche and Policard were of the opinion that the calcium used in the formation of callus came for the most part from the aseptic necrotic bone at the ends of the fracture fragments.

The bone which is necrotic retains a density greater than that of the living adjacent bone. This is so recognized in roentgenograms that are made after sufficient time has elapsed to permit atrophy of the bone which has retained a good blood supply. This relative difference in density is produced by the fact that the living bone atrophies following the fracture, while the bone which is deprived of its vascularity is unable to atrophy, having insufficient blood supply to take away the opaque mineral salts.

The following case reports demonstrate the typical course of a segmental fracture of a major long bone:

CASE 1. J. L., a male, aged fifty-three years, suffered a severe crushing injury to both legs on December 5, 1946. The fracture in the right leg was segmental, with a large, full-thickness fragment of tibia which included part of the proximal third and most of the middle third of the shaft (Fig. 4-A). This fracture was reduced accurately and internal fixation was secured with metal plates and screws. Eight months later, on July 24, 1947, there was very little evidence of union. Union was satisfactory by March 25, 1948, fifteen months after the fracture. However, the large segmental central fragment, which had never been completely detached from the surrounding soft tissue, still retained almost the same density that was present on the day of the accident (Fig. 4-B).

A more comminuted fracture with smaller fragments was sustained in the upper third of the left tibia. These fragments were adjusted for position, and fixation was maintained with a metal plate. Eight months after the injuries, the fractures in this leg were united.

These fragments were small and in contact with vascular soft tissue, and they either retained enough blood supply, by way of nutrient or periosteal blood vessels, to survive, or were rapidly transformed by creeping substitution to new bone of relatively normal density.

CASE 2. J. H., a male, aged forty years, suffered a complex simple fracture of the middle third of the right femur on May 31, 1946, when a large slab of concrete fell, striking him on the right thigh. A massive medial fragment of the femur was completely displaced from contact with the proximal and distal portions of the femoral shaft (Fig. 5-A). Although this was replaced at operation without detachment of the soft parts, it failed to undergo atrophy, but retained the density which we recognize in the roentgenograms as that of aseptic necrotic bone. This delayed, but did not prevent, union. Roentgenograms taken on January 17, 1947, seven months after fracture, showed that union was progressing slowly (Fig. 5-B).

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 1. These roentgenograms show a fracture of the right tibia with a detached fragment, representing more than the middle third and including the complete cortical circumference in one segment. It is a reasonable conclusion that the nutrient artery was either ruptured or entered the tibia above the proximal break, and that the middle fracture segment was nourished only by periosteal vessels.

Fig. 4-B: Fifteen months after injury, union has taken place. The segmental fragment, however, has retained greater density than have the metaphyseal fragments, indicating aseptic necrosis. Although union has occurred, the fracture ends of the metaphyseal fragments are also of greater relative density than bone more distal to the fracture sites.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 2. Roentgenogram of the right femur, showing a segmental fracture which occurred May 31, 1946.

Fig. 5-B: Seven months after fracture, there is evidence of aseptic necrosis and delayed union.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 3. Roentgenograms of simple segmental fractures of the right tibia and fibula. An open reduction was performed April 15, 1946, care being taken to avoid more stripping of the fragments than was absolutely necessary.

Fig. 6-B: Adequate union was present six months after fracture. There is less evidence of aseptic necrosis here than was illustrated for Case 1. The possibility that the nutrient artery may have still been intact and supplying the middle or segmental fragment would seem to be a reasonable conclusion.

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 4. Fracture of the humerus with a fragment which includes only about one-third of the total cortical circumference.
Fig. 7-B: Union with good alignment, three months after fracture; treatment was by hanging cast. The density of the fragment is similar to that of the adjacent cortex. The prognosis for survival of the more superficial osteoblasts in a small fragment is more favorable than for the segments which include a complete circumferential cortical fragment.

CASE 3. A. C., a male, aged fifty-seven, was admitted to Chicago Memorial Hospital on March 16, 1946, because of multiple injuries, including large segmental fractures of the tibia and fibula, without compounding (Fig. 6-A). The fracture fragments were aligned and immobilized by open reduction and internal fixation on April 16. Approximately five months after reduction, on September 13, roentgenograms showed evidence of bony union (Fig. 6-B). The patient was discharged from care with recovery of strength and function of this extremity, April 9, 1947, thirteen months from the time of injury. The large segmental fragment showed atrophy to a greater extent than did a similar fragment in Case 1.

The probability that an intact nutrient artery may have supplied this middle fragment was suggested by the favorable course of healing and by the fact that the retained density was less than would be compatible with a diagnosis of total aseptic necrosis.

CASE 4. O. B., a woman, aged forty-seven, was admitted to Chicago Memorial Hospital on January 27, 1948, because of an injury to the left arm. Roentgenograms showed a butterfly type of fracture of the middle third of the humerus. The separate middle fragment included only about one-third of the circumference of the shaft of the humerus and hence exposed a considerable amount of cancellous tissue to the serum, which is the ideal tissue-culture media (Fig. 7-A). This patient was treated with a hanging cast, and on April 23, three months after the injury, the fracture was united with abundant callus (Fig. 7-B).

It would appear to be a reasonable assumption that the medullary bone and the more superficially placed osteoblasts of the cortical fragment survived and took part in the healing of the fracture. The prognosis for survival of the detached fragment in a segmental fracture is more favorable when the fragment is small.

CASE 5. A. M., a woman, aged sixty-nine, was admitted to the Chicago Memorial Hospital * on July 19, 1947, because of a simple fracture of the lateral condyle of the left femur (Fig. 8-A). An open reduction and internal fixation by means of threaded pins and a single large screw were successfully carried out on July 22 (Fig. 8-B). Subsequent roentgenograms showed evidence of marked reduction in blood supply of the condylar fragment, indicated by failure of the bone to become atrophied, as did the adjacent femoral shaft and the medial condyle. However, approximately fourteen weeks after the injury, roentgenograms showed what appeared to be union of the fracture (Fig. 8-C). The patient was permitted to bear weight. Subsequent roentgenograms showed refracture and upward displacement of this lateral condyle (Fig. 8-D). The retained density of the aseptically necrotic condylar fragment with areas of decreased density representing absorption and replacement with creeping substitution are well illustrated.

This case demonstrates the importance of considering the possibility of aseptic necrosis in any detached major fragment of a fracture of a long bone. Immobilization should be maintained until there is roentgenographic evidence not only of union, but also of replacement of the aseptically necrotic bone by creeping substitution.

* Service of Sam W. Banks, M.D.

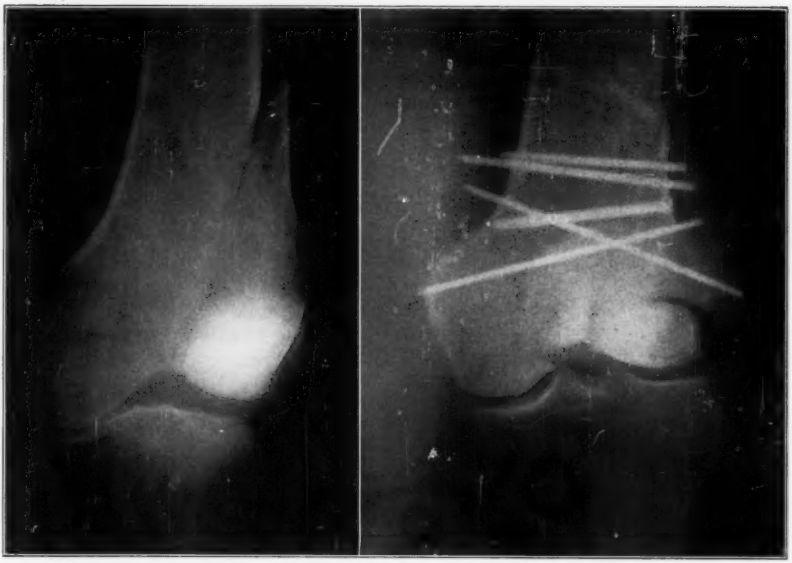

FIG. 8-A FIG. 8-B

Case 5. Illustrating the fate of a large condylar fragment, isolated from the nutrient artery. Open reduction may have stripped away some of the remaining periosteal and metaphyseal vessels.

FIG. 8-C FIG. 8-D

Fig. 8-C: This roentgenogram shows evidence of union, fourteen weeks after fracture, but the lateral condyle has retained the density that is typical of aseptic necrosis.

Fig. 8-D: When the patient attempted to walk, refracture occurred. (Courtesy of Sam W. Banks, M.D.)

COMMENT

With reasonable certainty we may predict a marked delay in union of large segmental fractures of the mid-shaft or ends of a major long bone. The larger the separate fragment in a segmental fracture in a long bone, the poorer the prognosis from the standpoint of

viability of that fragment. In the event that a fragment is partially devitalized and does not retain enough intact blood vessels to maintain a reasonable exchange of arterial and venous blood, some of the bone cells will die. If most of these cells die, the fragment will become necrotic, although massive sequestration does not occur. Union may then be delayed for many months. With good fixation, however, healing of the fracture will take place before the large fragment has undergone complete replacement by creeping substitution.

If a principal nutrient artery remains uninjured and supplies the large segmental fragment, aseptic necrosis may not occur, and the prognosis for undelayed healing of the fracture is good.

REFERENCES

1. Axhausen, Georg: Die histologischen und klinischen Gesetze der freien Osteoplastik auf Grund von Thierversuchen. Arch. f. Klin. Chir., **88**: 23–145, 1908–1909.
2. Axhausen, G., und Bergmann, E.: Die Ernährungsunterbrechungen am Knochen. *In* Henke, F., und Lubarsch, O.: Handbuch der speziellen pathologischen Anatomie und Histologie, Bd. 9, Teil 3. Berlin, Julius Springer, 1937.
3. Brunschwig, Alexander: Experimental Infarction of Bone Marrow. Proc. Soc. Exper. Biol. and Med., **27**: 1049–1051, 1930.
4. Cornil, V., et Coudray, P.: Du cal au point de vue experimental et histologique. J. de l'Anat. et de la Physiol., **40**: 113–179, 1904.
5. Doub, H. P.: Aseptic Necrosis of the Epiphyses and Short Bones. J. Am. Med. Assn., **127**: 311–317, 1945.
6. Greenberg, D. M., and Mohamed, M. S.: Effect of Lowered Blood Supply and of Glucose-l-Phosphate on Healing of Bone Fractures. Proc. Soc. Exper. Biol. and Med., **57**: 203–205, 1944.
7. Johnson, R. W.: A Physiological Study of the Blood Supply of the Diaphysis. J. Bone and Joint Surg., **9**: 153–184, Jan. 1927.
8. Leriche, R., et Policard, A.: Les problèmes de la physiologie normale et pathologique de l'os. Paris, Masson et Cie, 1926.
9. Phemister, D. B.: Repair of Bone in the Presence of Aseptic Necrosis Resulting from Fractures, Transplantations, and Vascular Obstruction. J. Bone and Joint Surg., **12**: 769–787, Oct. 1930.
10. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation. I. General Considerations and Changes Resulting from Injuries. Arch. Surg., **41**: 436–472, 1940.

DISCUSSION

Slipped Capital Femoral Epiphysis

(*Continued from page 22*)

the epiphysis, but also to put two grafts across the outside. I think a graft through the center of the epiphyseal line cannot be depended upon to cause fusion of the epiphysis.

Finally, I think these hips should be fixed with a Smith-Petersen nail just as early as the slipping can be demonstrated. I think they ought to be permitted to slip a little; otherwise hips will be nailed that may not have slipped. Just as soon as the diagnosis can be made, they should be nailed. You should not depend upon walking with crutches to prevent slipping. In the past two years, I have seen slipping occur in two hips while the patients were using crutches; both of them had slipped to a point where I thought I had to nail the hip, with resulting moderate deformity. I was afraid to take off the head because I had seen aseptic necrosis occur in two cases. It is quite difficult to get a bone peg in position.

I think in putting the nail in after the hip has begun to slip, you should put it as far posterior in the neck as possible. I notice that some of these nails just reached the top of the epiphyseal line. The nail should extend well into and fix the head.

TREATMENT OF THE NECROTIC HEAD OF THE FEMUR IN ADULTS *

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With the recent advance in knowledge of injuries and diseases of the hip—and especially with the great increase in the incidence of bony union following pinning and wiring of fresh fractures—aseptic or avascular necrosis of the head of the femur has come to be recognized as one of the most important and perplexing problems which confront the orthopaedic surgeon. Although aseptic necrotic lesions in adults are similar to those of childhood and adolescence, the differences are sufficiently great, particularly with reference to spontaneous repair and treatment, to require separate consideration.

Aseptic necrosis of the head of the femur in adults results from interruption of the circulation by either physical injury or non-traumatic occlusion of its blood vessels[3, 11, 12], injury being a more frequent cause than occlusion. Of the physical injuries producing aseptic necrosis of the head, fractures of the neck of the femur comprise the great majority, the remainder being dislocations and plastic operations designed to restore mobility of the hip joint. Of the non-traumatic lesions producing necrosis by occlusion of the vessels of the head, the one best known is caisson disease; in this condition, nitrogen gas, liberated from the blood and tissue fluids by too rapid decompression, somehow obstructs the circulation, either by embolism or by compression of the vessels of the bone by gas within its medullary tissues. The head of the femur is usually involved in multiple infarction of the epiphyses and diaphyses of the large bones. The other obstructing vascular lesions are more obscure and difficult to identify, but must result from embolism, thrombosis, or obliterating vascular diseases. They produce similar necrosis in the head of the femur, either alone or in association with infarcts of other parts of the skeleton.

Interruption of the blood supply to the head of the femur in adults causes death both of the bone and of the overlying articular cartilage, whereas in children all or most of the cartilage survives by nourishment derived from the synovial fluid. Such interruption of the blood supply may impair the hip joint by increasing the frequency of non-union of fracture of the femoral neck (if that is the cause of interruption of the capital blood supply), by production of pathological fracture and of collapse and disintegration of varying amounts of the weight-bearing necrotic portion of the head, and by causing late degenerative arthritis of the hip.

In general, a fracture of the neck of the femur unites more frequently if the head remains alive. This is because there is callus formation from the end of each fragment when the head survives, but only from the end of the distal fragment when the proximal or head fragment dies. In a series of forty-nine cases [10], studied before the efficient modern techniques for obtaining bony union by pin, threaded wire, or screw fixation of the fresh fracture were in common use, non-union was observed four times as frequently when the head died as when it remained alive. Some degree of degenerative arthritis usually develops in the hip joint, independently of whether or not an associated fracture of the neck unites or the dead head collapses. With improved methods of reducing and fixing fresh fractures by means of nails, screws, and threaded wires, bony union is obtained in the majority of cases in which the head fragment has been killed at the time of fracture by tearing of its blood vessels[4]. Collapse of a portion of the necrotic head of the femur takes place as a result of pressure upon it from the acetabulum. This does not occur if the fracture of the neck remains ununited, since then the head cannot bear sufficient weight; but a gradual invasion

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

FIG. 1-A

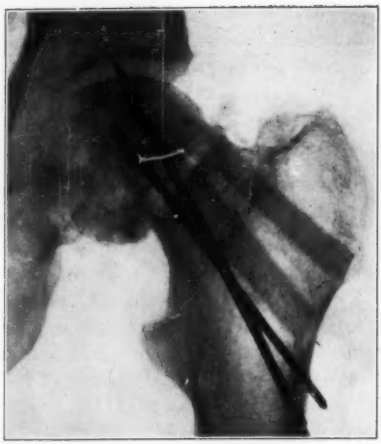

FIG. 1-B

Fig. 1-A: Case 1. Fracture of neck of femur and necrosis of head of nine months' duration. Non-union of fracture and partial replacement of lower portion of head by new bone of low density. Inset shows roentgenogram of slice of a similar dead head, confirmed by microscopic examination.
Fig. 1-B: One week after operation.

of such a necrotic head by blood vessels and osteogenic tissue usually occurs by way of untorn portions of capsule, the round ligament, and adhesions; and a variable amount of the dead bone becomes replaced by a less dense disuse type of new bone. During the first two or three years the head is usually so well preserved that operative treatment and proper postoperative protection may bring about bony union of the fracture fragments, replacement of the dead tissues by living tissues without collapse, and a good functional result.

Using Compere and Lee's technique of open reduction of the ununited fracture and fixation by two tibial bone grafts and threaded wires, the author placed the drill holes and inserted the rectangular pegs into the necrotic upper half of the head of the femur in Case 1. The patient was operated upon nine years ago.

CASE 1. H. A., a woman, fifty-two years old, had had an ununited fracture of the neck of the left femur for nine months. Roentgenographically, the upper portion of the head possessed an even density which was slightly greater than that of the atrophic bone of the trochanteric regions. Most of the lower portion of the head showed marked blotchy reduction in density (Fig. 1-A). A diagnosis was made of death of the head with blotchy revascularization and replacement of its lower portion by fine spongy new bone. The picture is somewhat similar to that of the inset on Figure 1-A, which shows a roentgenogram of a slice of dead head, excised in a case of non-union of ten months' duration. Microscopically, the dense area above and laterally consisted of old dead bone, and the rarefied inferior portion had been replaced by finely trabeculated new bone.

Through a Smith-Petersen incision, the fracture was reduced and two one-centimeter drill holes were made to converge from the side of the shaft through the neck and deep into the remaining upper portion of the head. One was placed just beneath the articular cortex of the upper portions of the neck and head. The drill removed a proportionately large amount of the remaining necrotic head. Rectangular tibial bone grafts were inserted into the drill holes; they acted as struts to prevent collapse of the head and to bridge the fracture line. The remaining space in the drill holes permitted upward growth of callus from the neck into the head, with invasion of the remaining dead bone and replacement by new bone. The three threaded wires, inserted through the head and neck, gave additional fixation of the fracture (Fig. 1-B).

A roentgenogram at the end of two months revealed evidence of bony union of the fracture fragments (Fig. 1-C). The patient continued to walk on crutches until eight months after the operation, at which time a roentgenogram revealed extensive reconstruction of the upper portion of the head (Fig. 1-D). The threaded wires were then removed, since one of them projected into the joint. Walking was resumed with no discomfort, and there was a good return of function. There was roentgenographic evidence of progressive replacement at ten months (Fig. 1-E); thirteen months after operation the upper portion of the head was

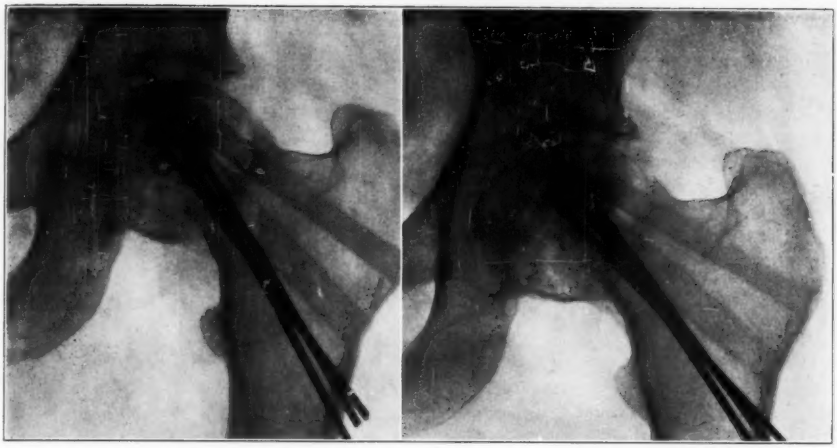

FIG. 1-C FIG. 1-D

Fig. 1-C: Two and three-quarters months after operation.
Fig. 1-D: Eight months after operation.

FIG. 1-E FIG. 1-F

Fig. 1-E: Ten months after operation, fracture has united and head shows extensive reconstruction.
Fig. 1-F: Seven and one-half years after operation, the roentgenogram shows reconstruction of the head without collapse; there is a minimal degree of arthritis. Function is excellent.

normal in contour and, except for parts of the grafts, appeared to have been entirely reconstructed. From that time onward the function of the hip joint was normal, aside from very slight limitation of flexion; a roentgenogram taken seven and one-half years after the first operation revealed a similar appearance, with no collapse of the weight-bearing portion and with minimal arthritic changes in the joint (Fig. 1-F).

The evidence indicates, first, that the drilling not only removed much of the dead bone, but also permitted rapid invasion and transformation of that which remained in the upper portion of the head; and, second, that the bone pegs served to prevent fracture and collapse of the head as well as to facilitate union of the fracture.

Bone-drilling and bone-pegging operations have usually been done primarily to obtain

bony union of the fracture [1, 2], whether fresh or ununited, and the grafts have most frequently been placed roughly in the central portion of the head, whether it is dead or alive. Both threaded wires and pins and nails, as the Smith-Petersen type [7], have been used for additional fixation of the fracture. A cursory review of roentgenographic illustrations of some of the published cases reveals that, when the head is dead, it sometimes becomes transformed after bony union and does not collapse; while in other instances, probably more frequently, it collapses and a poor result is obtained. Since the excellent long-term result observed in Case 1, previously reported by Sherman and Phemister, three additional patients with non-union, necrosis of the head, and erosion of the neck have been operated upon within the past thirteen months by the insertion of a single graft and three threaded

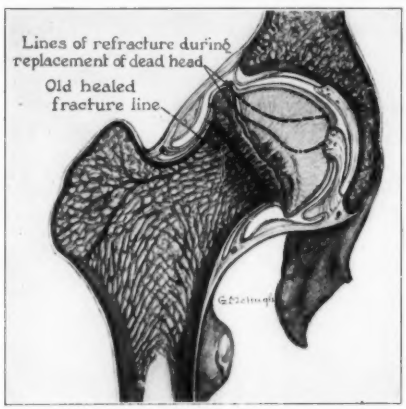

FIG. 2

FIG. 3

Fig. 2: Sketch of healed fracture of neck and necrosis of head fragment with refracture and collapse from weight-bearing when the weak part of the zone of creeping substitution reaches the upper margin of the head, beneath the lateral margin of the acetabulum. The downward and medialward course of the fracture line varies with the extent of invasion of the lower portion, as indicated by the lines. The line nearest the neck has been sketched from Fig. 3.

Fig. 3: Microscopic section of excised dead head and proximal portion of neck, including old subcapital fracture site (Case 5 of Sherman and Phemister). Refracture and displacement through zone of replacement of head, extending from beneath margin of acetabulum above to margin of articular cartilage below (nineteen months after injury).

wires into the central and upper regions of the head. The fracture has united in all cases and there has been extensive invasion and transformation of the head, but the time has been too short for the end results to be known.

In drilling operations alone [5, 8], performed for enhancing bony union and for replacement of dead bone, the multiple drill holes have been more or less evenly distributed within the head and neck.

If non-union persists for three or more years, the dead head frequently becomes so extensively disintegrated and adherent that bony union of the fracture and good hip function cannot be obtained by operation. Treatment of such neglected cases should usually be by excision of the head and the performance of some type of plastic reconstruction operation [9, 14], or by ankylosis of the hip.

The treatment of aseptic necrosis of the head of the femur, in cases in which the neck is intact, may be approached in a manner similar to that which has just been described for ununited fracture of the neck of the femur with necrosis of the head. This includes cases in which the neck has been fractured and has undergone bony union, as well as those in which the necrosis was caused by dislocation of the hip or by vascular occlusion. If the hip is protected for the first two or more years by avoidance of weight-bearing, the head may be

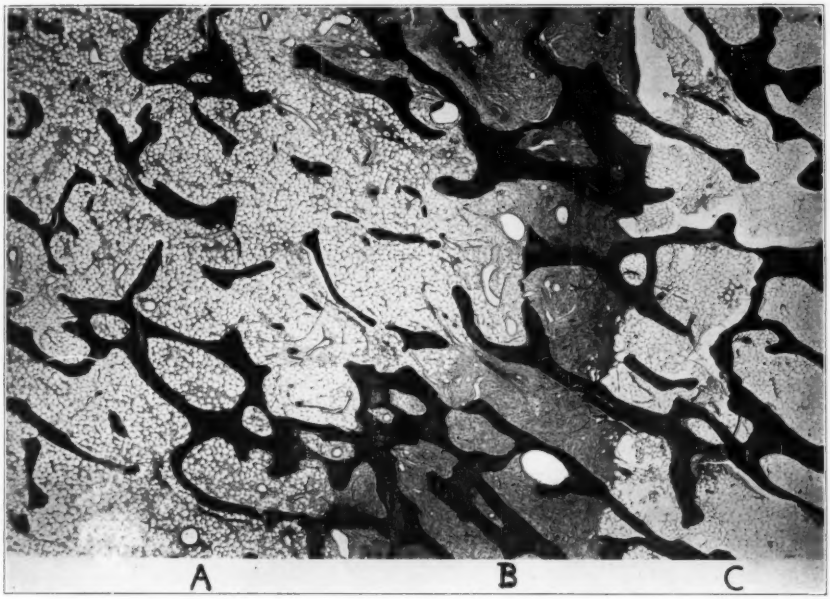

FIG. 4

Photomicrograph (× 12) shows zone of creeping substitution of dead bone of head by new bone in a case of [illegible]d fracture of neck of femur of eight months' duration.
A: [illegible], substitution of dead trabeculae by temporarily weaker new trabeculae, and differentiation into [illegible] and hemopoietic marrow.
B: Creeping invasion of fibrous callus.
C: Dead bone and dead marrow. Trabeculae larger than those in Zone *A*.

invaded and replaced by new bone without change in contour. Such abstinence from weight-bearing is rare, however, and there is subsequent fracture of the head in the great majority of cases, with more or less collapse and disintegration of the broken-off necrotic portion. The patient usually walks with little or no difficulty for six to eighteen months after the occurrence of the necrosis. During this time it is usually difficult to diagnose the presence of necrosis roentgenographically, because the contour of the head is normal and there is little difference in density between the dead bone of the head and the neighboring living bone which, being used in weight-bearing, shows little atrophy of disuse. Then gradually increasing pain, weakness, and stiffness in the hip are experienced; a roentgenogram shows fracture and beginning collapse of the weight-bearing portion of the head and more definite reduction in density of the living bone of the trochanters, resulting from disuse.

Usually the fracture and collapse occur when the slow process of invasion, absorption, and substitution of new bone from the neck approaches or reaches the lateral margin of the upper portion of the head; this portion is in contact with the acetabulum, and the new bone receives the weight transmitted from it. The damage occurs here because the newly formed bone in the zone of creeping substitution is, for many days, weaker than the old dead bone which it has replaced, and it will not withstand weight-bearing during that period. This occurrence, which is appreciated all too little, is the crux of the collapse problem. The narrow zone of new bone is fractured and the remaining dead bone is displaced downward by pressure from the acetabulum. Fracture and collapse may happen after varying degrees of invasion and replacement of the lower portion of the head (Fig. 2). Occasionally the fracture line and the displacement run downward through the head, from

FIG. 5

Sketch of drilling and pegging of necrotic head in various stages. Ingrowths from neck alongside the grafts and from round ligament help to replace dead bone and cartilage.

the acetabular margin at the upper limit to the junction of the head and neck on the undersurface. This is shown by the unbroken line of Figure 2, which was sketched from the microscopic section shown in Figure 3. Usually there is more rapid invasion in the lower region than in the upper; and the line curves medially and terminates about the level of the fovea or, more frequently, somewhat higher.

Figure 3 shows a microscopic section of the head and proximal portion of the neck of the femur, excised nineteen months after an impacted subcapital fracture, which caused necrosis of the proximal fragment and was followed by bony union. The invasion and replacement by new bone had recently reached the top of the head at the acetabular margin and had extended downward into the margin of the head below. A fracture had occurred through the narrow zone of weak new bone in the zone of creeping substitution, and the dead portion of the head had collapsed from pressure against the acetabulum. Microscopic examination, previously reported [13], revealed necrosis of both bone and cartilage in the head, proximal to the new fracture line, except for some invasion from the fovea and replacement of some of the articular cartilage inferior to it by new bone and marrow. The dead cartilage over the living bone of the top of the head, lateral to the acetabular margin, had been replaced by fibrocartilage.

If there is early revascularization and new-bone replacement of the medial and inferior portions of the head, or if the inferior portion is not killed, as in some cases of caisson disease, a bowl-shaped fragment of the upper and central portions may break off. Figure 4 shows a microscopic section of a zone of creeping substitution, through which the patho-

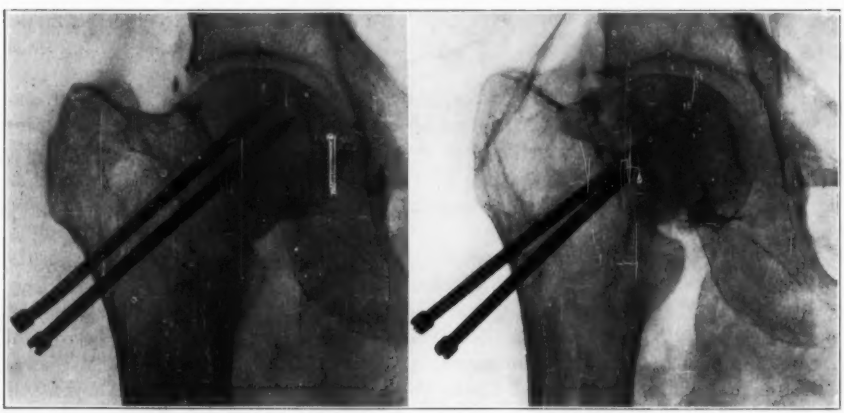

FIG. 6-A FIG. 6-B

Fig. 6-A: Case 2. Twenty months after primary nailing, fracture has united. Dead head is slightly more uniform and dense than living trochanteric region, which is atrophic from disuse.

Fig. 6-B: Seven months later, pins are working out. Refracture has occurred at junction of head and neck, with slight downward displacement of head. Trochanters are still more atrophic, while head retains former density, indicating that it is dead.

FIG. 6-C FIG. 6-D

Fig. 6-C: Two months after operation, fracture has united.
Fig. 6-D: Six months after operation, head is extensively transformed.

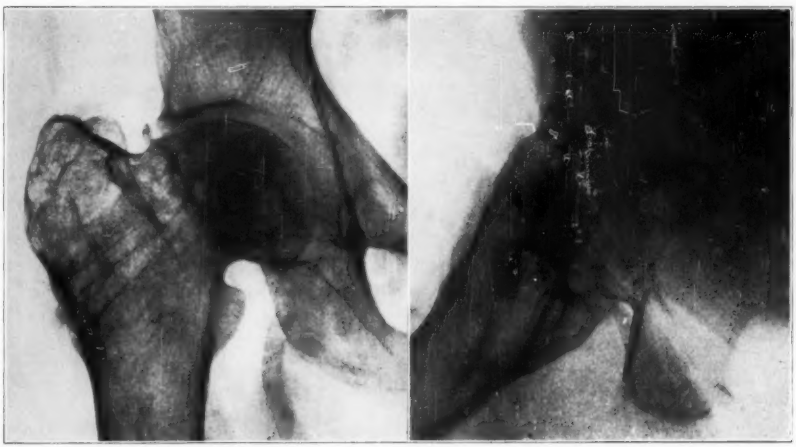

FIG. 6-E FIG. 6-F

Fig. 6-E: Seven and one-half months after operation.
Fig. 6-F: Twelve and one-half months after operation, the head has apparently been replaced by new bone without change in contour.

logical fracture takes place if weight is thrown upon it. *C* is the dead bone of normal density; *B* is the zone of invasion of the cancellous spaces by fibrous callus; and *A* is the zone of metaplasia in which the fibrous callus becomes differentiated into cancellous weak new bone and marrow, simultaneously with absorption and replacement of the dead trabeculae.

The earliest sign of aseptic necrosis of the head in the presence of an intact femoral neck is usually the beginning downward displacement of the broken-off weight-bearing portion, or in some cases the roentgenographic evidence of greater density of the non-atrophic head as compared with the atrophied living bone of the trochanters.

Experience in Case 2 suggests that, as soon as the presence of necrosis of the head of the femur can be established in this group, drilling and bone-grafting should be carried out in a manner similar to that practised in the case of ununited fracture of the neck and necrosis with little disorganization of the head; and, if performed before there is downward displacement and erosion of the broken-off portion, a successful outcome should be obtained.

CASE 2. E. M., a woman, sixty years old, sustained a fracture of the neck of the right femur, the line passing upward and outward from just distal to the mid-portion of the inferior cortex to the superior cortex, near its junction with the head. The fracture was treated initially by closed reduction and fixation with steel nails; bony union followed. The patient walked with two crutches for about a year, and then with a crutch and cane. The hip was mobile and almost painless, but weak, at the end of twenty months. At that time a roentgenogram (Fig. 6-A) revealed a shortened neck, impacted below, and bony union of the fracture. There was reconstruction of the lower portion of the proximal fragment of the neck and a uniform shadow of most of the head of the femur, which was slightly more dense than that of the adjacent atrophic living bone of the trochanteric regions. These findings were indicative of an unreplaced necrotic head and of replacement of the necrotic head fragment of the neck by new bone, invading across the healed fracture. Walking with a crutch was continued, but the hip soon became painful and weak, and the use of two crutches was resumed. A roentgenogram taken seven months later (Fig. 6-B) revealed evidence of an irregular line of pathological fracture, extending downward through the lateral margin of the articular surface of the head, lying beneath the acetabular margin above, to the junction of the head and neck below. There had been loosening and slight extrusion of the pins and slight downward displacement of the dead head. The shadow of the trochanteric regions was more reduced in density, since it had undergone further disuse atrophy, while the density of the head was unchanged. The fracture had taken place through the zone of invasion and replacement of the dead fragment by new bone, when its upper portion reached the margin of the acetabulum and weight fell upon it.

At operation, the pins were driven deeper into the head, and two holes were drilled through it with a one-centimeter drill, one being beneath the pins and the other above; each penetrated the head and extended into the joint. Rectangular bone grafts, taken from the opposite tibia, were inserted into the holes. The upper pin and graft extended across the joint and were withdrawn to just within the head. It was possible for fibrous callus to grow alongside the rectangular grafts in the drill holes, across the line of pathological fracture, and to invade and replace the remaining dead bone by new bone; and for fibrous tissue to grow out onto the articular cartilage, which becomes absorbed and replaced by fibrocartilage. This is shown as part of a composite sketch (Fig. 5).

Roentgenograms taken two months and six months after operation (Figs. 6-C and 6-D) show evidence of bony union of the fracture; and subsequent roentgenograms, up to twelve and one-half months after operation (Figs. 6-E and 6-F), reveal a gradual replacement of all dead bone by new bone without change in contour of the head. The hip is painless, motion is almost normal, and partial weight-bearing has recently been resumed.*

The result obtained is thus far similar to that in Case 1, and the two cases indicate that the operative procedure is based upon sound principles.

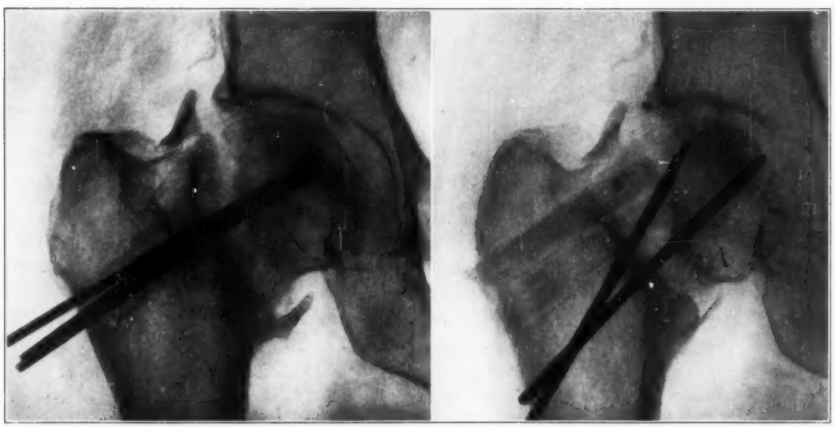

FIG. 7-A FIG. 7-B

Fig. 7-A: Case 3. Twenty-five months after fracture, limb was being used in walking, and little difference in density was apparent between head and trochanters.

Fig. 7-B: Four and one-half months after drilling, pegging, and re-wiring. Fracture has united, although line was not exposed or callus cleaned out. Upper tibial graft does not enter top of head.

* Seventeen months after operation, the contour of the head was still intact.

In Case 3, with ununited fracture of the neck and death of the head, the upper graft was carried across the ununited fracture line to the margin of the superior portion of the head, while the lower graft penetrated the head deeply. The fracture united, but the top of the undrilled and unpegged head broke down after sixteen months, and an unsatisfactory result has been obtained.

CASE 3. F. S., a woman, sixty-six years old, had a subcapital fracture of the neck of the right femur. Treatment was by open reduction, fixation with three threaded wires placed close together, and onlay chips from the ilium across the fracture line. Density studies in subsequent roentgenograms indicated death of the head. Non-union resulted, and the neck gradually shortened as a result of erosion of fragments from walking. Figure 7-A shows the condition twenty-five months after injury. Through a lateral incision, two additional wires were inserted across the neck into the head, after which the three old wires were removed. A one-centimeter drill was then inserted along the pathway of the old wires through the head and, as a result of miscal-

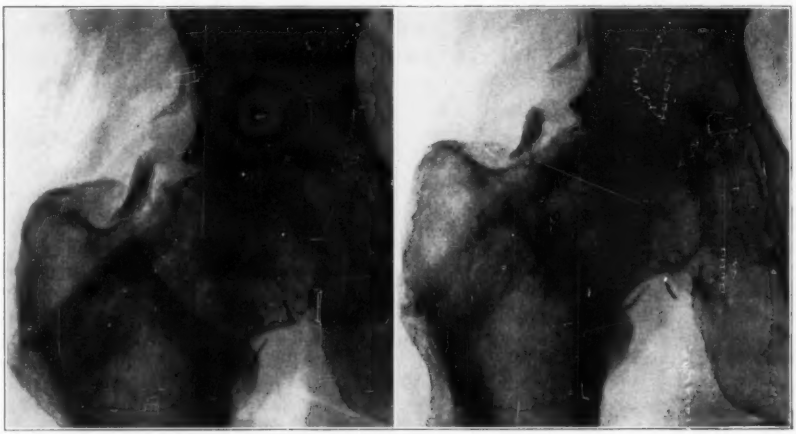

FIG. 7-C FIG. 7-D

Roentgenograms show union of fracture and progressive transformation of lower portion of head.
Fig. 7-C: Nine and one-half months after operation.
Fig. 7-D: Sixteen and one-half months after operation.

FIG. 7-E

Twenty-two months after operation. Roentgenograms show breaking down and absorption of top of dead head, into which the upper graft did not extend.

culation, for a short distance into the acetabulum. The articular cartilage of the head was thus open to invasion and replacement from the drill hole. A rectangular bone graft from the tibia was inserted deep into the head. A second hole, drilled through the upper portion of the neck, extended for only a short distance into the lateral portion of the head; and a similar bone graft was inserted the length of the hole, barely bridging the fracture line. This left the upper portion of the dead head intact. The fracture united promptly, despite the fact that the fracture line was not exposed or curetted (Fig. 7-B).

The patient walked with a cane after four months, and the wires were removed after eight months. The middle and lower portions of the head were gradually transformed (Fig. 7-C). Fair hip function was regained with relatively little pain, and the contour of the top of the head was normal, sixteen and one-half months after the last operation (Fig. 7-D). Pain and stiffness then developed and the patient soon resumed the use of crutches. The pain continued, and twenty-two months after the second operation, roentgenograms showed breaking down and absorption of the top of the head (Fig. 7-E).

A similar result was recently seen in a patient treated elsewhere by threaded pins and a bone graft inserted through the center of the head. Had drilling and insertion of the bone graft through the entire length of the upper portion of the head been carried out, the result might have been comparable to that obtained in the first two cases.

In the presence of an intact femoral neck, cases of long-standing necrosis of the head with marked collapse, deformity, and degenerative arthritis may require treatment by some type of plastic procedure, such as the Vitallium-cup arthroplasty, or by arthrodesis of the hip.

In cases with persistent dead bone and less extensive deformity, an endeavor may be made to obtain replacement of the necrotic areas by new bone, and improvement in the structure of the head by drilling and bone-pegging procedures directed at the necrotic bone. Two such patients have been operated upon; their histories will be briefly recorded here, although the time elapsed is too short for the end results to be known.

Case 4. R. Y., a male, aged thirty-one, was admitted to the Clinic three years after he had sustained an intracapsular fracture of the neck of the right femur. Primary fixation of the fracture had been accomplished by means of a Smith-Petersen nail, inserted through the upper portion of the neck and about one-half the length of the head. Bony union followed, and use of the extremity was resumed with almost complete freedom from symptoms. Twenty-nine months after the operation the patient began to have pain, weakness, and stiffness in the right hip, which progressed slowly. A roentgenogram on admission revealed union of the cervical fracture and evidences of transformation of the inferior and lateral portions of the head into new bone. The superior portion of the head, medial to the margin of the acetabulum, was broken off above the point of the nail and was separated by a zone of reduced density, compatible with non-union. It cast a slightly denser shadow than the adjacent transformed bone, and was slightly displaced downward. At operation the nail was removed and the old channel was entered with a one-centimeter drill, which was carried through the detached portion of the head. A second drill hole was made, beginning just below the first hole and being carried slightly backward and upward into the posterior part of the detached portion. Rectangular tibial bone grafts were inserted into the holes. Roentgenograms revealed that the grafts extended across the ununited fracture line, but not through the entire thickness of the necrotic area to the joint surface.

The patient has been kept on crutches for seven months, and series of roentgenograms have shown evidence of bridging of most of the ununited fracture line, but the fragment does not yet appear to be completely replaced by new bone.

Case 5. F. B., a male, aged thirty-eight years. This patient had been followed for twelve years, because of slowly progressive fibrocystic disease in the head of each femur, more marked in the right, where there was extensive degenerative arthritis. Serial roentgenograms showed what appeared to have been a large area of aseptic necrosis at the top of the right head, overlying a cavity which had caused it to break off. It had organized slowly, but a portion appeared to be still separated by an ununited fracture line. In the past two years, similarly, the thin roof above the cavity in the top of the left femoral head had broken off and appeared to be collapsed and ununited. The left hip was only slightly impaired, but there was marked limitation of motion, moderate pain, and roentgenographic evidence of degenerative arthritis in the right hip.

Five and one-half months ago the left hip was operated upon. Two holes, each one centimeter in diameter, were drilled the length of the neck into the partly sclerotic, partly cystic area of the upper portion of the head, and rectangular tibial bone grafts were inserted almost to the articular cortex. Two weeks later the right hip was operated upon. A hole was drilled the length of the neck only, and aimed at the medial portion of the necrotic ununited fragment at the top of the head. A circular drill was then used and carried through into the joint, thereby obtaining a core of the area for microscopic examination. A second hole was drilled

beginning just below the first and carried through the neck posterior and lateral to the first. Again with the circular drill, a core was cut, extending the length of the head into the joint. Rectangular tibial pegs were inserted the length of the holes. Series of roentgenograms have shown that the grafts have become attached to the broken-off fragment which is undergoing transformation and fusion with the head.

The cannulated drills and guide wires and the circular biopsy drills and obturator are shown in Figure 8. The results of biopsy of the head of the femur by this technique will be published in a later report.

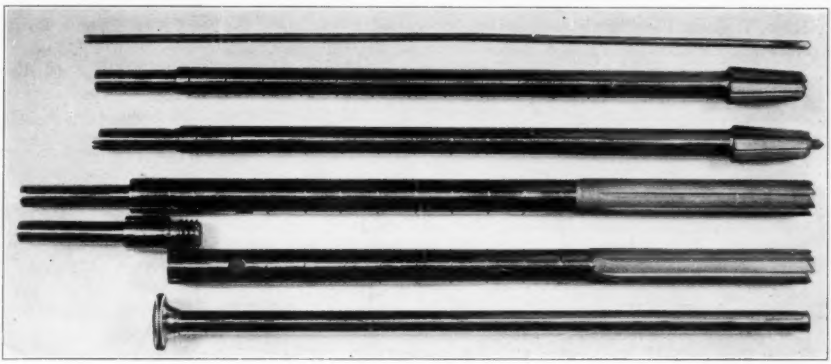

FIG. 8

Above, modified Albee drills and guide wires. Below, circular drills and obturator for obtaining biopsy specimen from head.

SUMMARY AND CONCLUSIONS

Two cases of necrosis of the head of the femur, one associated with an ununited fracture of the neck and the other with an ununited fracture at the junction of the head and neck, which developed after healing of a primary fracture located distally in the neck, were treated by drilling two holes across the neck and upper portion of the head and the insertion of a rectangular tibial bone graft into each hole. The fractures united promptly and the upper portion of the head was rapidly invaded and replaced by new bone, thereby avoiding collapse of the head from weight-bearing. In one patient, function was restored practically to normal and there was little roentgenographic evidence of degenerative arthritis, seven and one-half years after operation. An equally promising result was present in the other patient at the end of twelve and one-half months.

In a third case of ununited fracture with death of the head of two years' duration, the lower bone graft was inserted across the fracture line deep into the head, while the upper graft was inserted only to the margin of the upper portion of the head. Bony union occurred promptly; but, beginning sixteen months after operation, the upper portion of the head, which had not been drilled and supported by a graft, underwent collapse and absorption, and a poor functional result was obtained.

The cases present evidence that drilling and bone-pegging of the upper portion of the necrotic head of the femur which has undergone little or no collapse may increase the rate of transformation of the structure into living bone, shorten the non-weight-bearing period, and decrease the incidence of collapse, deformity, degenerative arthritis, and poor functional results.

REFERENCES

1. ALBEE, F. H.: The Bone Graft Peg in the Treatment of Fractures of Neck of Femur. Author's Technic. Ann. Surg., **62:** 85–91, 1915.
2. ALBEE, F. H.: Bone Graft Surgery. Philadelphia, W. B. Saunders Co., 1915.
3. AXHAUSEN, G., und BERGMANN, E.: Die Ernährungsunterbrehungen am Knochen. *In* Henke, F., und Lubarsch, O.: Handbuch der speziellen pathologischen Anatomie und Histologie, Bd. 9, Teil 3. Berlin, Julius Springer, 1937.

4. Boyd, H. B., and George, I. L.: Complications of Fractures of the Neck of the Femur. J. Bone and Joint Surg., **29:** 13–18, Jan. 1947.
5. Bozsan, E. J.: Compression of Cancellous Bone. Principal Manifestations in the Head and Neck of the Femur. Treatment by Connecting Drill Channels. Am. J. Surg. (Special Monograph), **53:** 537–618, 1941.
6. Compere, E. L., and Lee, John: The Restoration of Physiological and Anatomical Function in Old Ununited Intracapsular Fractures of the Neck of the Femur. J. Bone and Joint Surg., **22:** 261–277, Apr. 1940.
7. King, Thomas: The Closed Operation for Intracapsular Fracture of the Neck of the Femur. Final Results in Recent and Old Cases. British J. Surg., **26:** 721–748, 1939.
8. Kleinberg, Samuel: Aseptic Necrosis of the Femoral Head Following Traumatic Dislocation. Report of Two Cases. Arch. Surg., **39:** 637–646, 1939.
9. Moore, J. R.: Cartilaginous-Cup Arthroplasty in Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **30-A:** 313–329, Apr. 1948.
10. Phemister, D. B.: Fractures of Neck of Femur, Dislocations of Hip, and Obscure Vascular Disturbances Producing Aseptic Necrosis of Head of Femur. Surg., Gynec., and Obstet., **59:** 415–440, 1934.
11. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation. I. General Considerations and Changes Resulting from Injuries. Arch. Surg., **41:** 436–472, 1940.
12. Phemister, D. B.: Changes in Bones and Joints Resulting from Interruption of Circulation. II. Nontraumatic Lesions in Adults with Bone Infarction; Arthritis Deformans. Arch. Surg., **41:** 1455–1482, 1940.
13. Sherman, M. S., and Phemister, D. B.: The Pathology of Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **29:** 19–40, Jan. 1947.
14. Smith-Petersen, M. N.; Larson, C. B.; Aufranc, O. E.; and Law, W. A.: Complications of Old Fractures of the Neck of the Femur. Results of Treatment by Vitallium-Mold Arthroplasty. J. Bone and Joint Surg., **29:** 41–48, Jan. 1947.

DISCUSSION

Congenital Pseudarthrosis

(*Continued from page 39*)

splint. These were young children, most of whom had had one or more previous grafting operations. In three months all had solid bony union with a large amount of external callus.

Dr. Trueta's explanation of this was essentially as follows: The lesion is the site of a constant deforming tension of the posterior soft tissues, which introduces a disturbance of immobilization before a graft alone or new-bone formation can be strong enough to withstand it. He believed that the entire bone length of the intramedullary splint, obtained without stenosis of the medullary circulation, allows such complete immobilization as to permit normal callus formation to develop to effective maturity.

It seemed to me that this theory and the results secured confirmed the value of external immobilization in the achievement of Dr. Moore's brilliant and promising results in this otherwise discouraging condition.

Dr. John R. Moore (closing): I wish to thank the discussors for their valuable contribution to this paper.

I would like to emphasize two points which are deemed vitally essential to the success of the method presented. First, primary fixation, including pins and plaster, must be maintained until the continuity of the medullary cavity has been restored, which may require from six to nine months or longer. The tibial and fibular shafts do not have sufficient strength to withstand the normal physical stresses until the medullary cavity has reformed. The second point is the necessity of reinforcing the site or sites of the osteosynthesis, if narrowing or bending is taking place, in order to prevent refracture. Common sense demands that this be done before the fracture occurs, and not afterward.

The presence of increased alkaline phosphatase in the delayed graft, in the three or four cases analyzed, is believed to be further evidence that immature bone is being transplanted.

Dr. Peabody's mention of Dr. Trueta's work is interesting. I am quite sure that fixation is very important.

Dr. Phemister called attention to the importance of doing control operations with this same type of fixation. That, too, is important.

Dr. Green has covered thoroughly the basis of the problem, and I agree with his conclusion that further study is necessary.

INTRACAPSULAR FRACTURES OF THE FEMUR TREATED WITH A COMBINED SMITH-PETERSEN NAIL AND FIBULAR GRAFT *

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In 1941, two important papers were published on the results of the treatment of intracapsular fracture of the neck of the femur with the Smith-Petersen nail. One paper was prepared by the Fracture Committee of The American Academy of Orthopaedic Surgeons and dealt with 144 cases fixed with a trifin nail alone, as well as with cases treated by other forms of fixation. The second paper, by Eyre-Brook and Pridie, assessed the results in fifty-two patients treated with a trifin nail. The figures given in each paper were similar,—only some 70 per cent. of cases achieved bony union. Each series was based on a minimum follow-up period of one year. Had a longer minimum period been taken, the figures for aseptic necrosis would undoubtedly have been larger; but as it was, these results showed that the use of a trifin nail alone was far from being the ideal treatment of intracapsular fractures.

It was shortly after the publication of these two papers that the author began to treat all intracapsular fractures with a Smith-Petersen nail and a fibular graft, and since the beginning of 1942, 107 such cases have been thus treated in the Orthopaedic Department of the Glasgow Royal Infirmary.

The complete fixation afforded initially by a trifin nail depends on the physical pressure exerted between the nail and the bone into which it is driven. Only in dead bone are this pressure and fixation maintained for any length of time. Normal vascular bone reacts to physical pressure by local absorption of the bone, and this occurs no matter how inert the metal is, although ionizable material certainly accelerates this reaction. It is for this reason that the nail loses its firm grip within a few weeks of operation. When a graft is added it provides only an imperfect degree of fixation at first, but it soon fuses with the surrounding bone, and thus the complete immobilization of the fracture is maintained.

The fibula was chosen as the source of the graft, because of its strong tubular shape and because it has less dense cortical bone in its structure than has a tibial graft. In old people, regeneration of the fibula does not occur, but the absence of six inches of the fibula appears to cause no disability, whereas removal of a similar length of graft from the cortex of the tibia is often followed by pain and tenderness for many months and the defect left may predispose to fracture of the tibia.

Previous papers have referred to the use of a combined nail and fibular graft in intracapsular fractures of the neck of the femur, but generally only in cases of non-union. King, however, referred in 1939 to the fact that he had begun to use the combined nail and graft in all cases.

TECHNIQUE OF OPERATION

Preoperative Treatment

Prior to operation the lower extremity is immobilized with sandbags, and no traction or other attempt at reducing the fracture is carried out. A spinal anaesthetic of 5 per cent. procaine is invariably employed, and in old patients no preoperative sedative is used. Elderly people rarely, if ever, have headache following a spinal anaesthetic and they are seldom apprehensive. The giving of morphine to them before spinal anaesthesia may precipitate collapse.

The patient is placed on an orthopaedic table and reduction of the fracture is ob-

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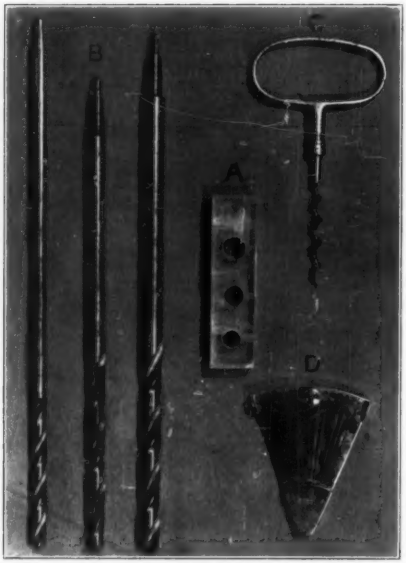

FIG. 1

Special Instruments used in Operation.

A: Perspex gauge, three-quarters of an inch thick, with three holes, one-half inch, seven-sixteenths of an inch, and three-eighths of an inch, respectively, in diameter. (Each hole is actually one thirty-second of an inch wider than this.)

B: Three long-shanked drills, one-half inch, seven-sixteenths of an inch, and three-eighths of an inch in diameter, respectively. The slightly wider gauge holes ensure a firm fit for the fibular graft in the drill holes.

C: Corkscrew which grips lumen of fibular graft well and may be used for withdrawing the graft.

D: Author's director. A simple and cheap instrument, similar in principle to the Engel-May model.

tained by slight traction and full internal rotation of the limb. Occasionally the Leadbetter method of reduction has been employed, where good reduction could not otherwise have been obtained.

Operation

The trifin nail is inserted in much the same way as is generally employed when the nail is used alone, but a greater degree of accuracy is demanded in order to leave room for the graft. In the first few cases the graft was placed below the nail, but as it proved technically easier to insert the graft above, this procedure was adopted in all subsequent cases.

After the patient is fixed on the table, anteroposterior and lateral roentgenograms are taken to assess the accuracy of the reduction and to determine the precise point of entry of the guide wire through the cortex. From the roentgenogram an assistant calculates the distance of this point from the ridge at the base of the greater trochanter to which the vastus lateralis is attached,—this attachment being, of course, the chief landmark in the operation. A halfpenny may be held against the trochanter when the preliminary anteroposterior roentgenogram is taken. The coin measures exactly one inch in diameter, and no matter how it is held, its shadow on the film gives an index of the degree of magnification which has to be allowed for in any measurement.

The calculated distance of the cortical hole from the trochanteric ridge is measured with calipers, and a triangular hole in the cortex of the femur is made. This hole is made toward the front or back of the shaft, depending on the degree of anteversion of the neck as determined by inspection of the lateral roentgenogram. After the guide wire has been inserted low in the neck, the trifin nail is driven in according to the usual manner.

FIG. 2

Case 43. Lateral roentgenogram showing how spikes of bone engaged and prevented reduction. Non-union resulted. Note the shadow of the director illustrated in Fig. 1,*D*.

In the intervals, while the roentgenograms are being developed, the graft is cut from the lower half of the fibula. To prevent the fibula from splintering, it is first weakened by several drill

holes at the line of section. The muscular ridges on the graft are removed with a file until the whole graft can be just passed through one of three holes on a perspex gauge (Fig. 1,*A*). These holes measure one-half inch, seven-sixteenths of an inch, and three-eighths of an inch, respectively. The fibular graft is then sawed to the exact length of the trifin nail, which at this stage should be in place.

A guide wire is passed along the hole in the nail, a long twist drill of the appropriate diameter (Fig. 1,*B*) is taken on a brace, and a hole is bored above and parallel to the guide wire. The required depth is marked on the drill; it is desirable to have the penetration of the graft one-quarter inch less than that of the nail. The long shank on the drill is necessary in order to keep the handle of the brace from striking against the side of the thigh. The drill is kept turning in the same clockwise direction when being withdrawn, in order to remove all the drillings. The graft is then tapped into place, but one should make sure that it remains parallel to the guide wire as it goes in. In ununited fractures the graft may catch on the sclerosed bone as it crosses the fracture line and may deviate from the channel drilled for it. After final check roentgenograms, the wound is closed and the dressing is fixed with an elastoplast spica in order to make it secure against subsequent knee-flexion

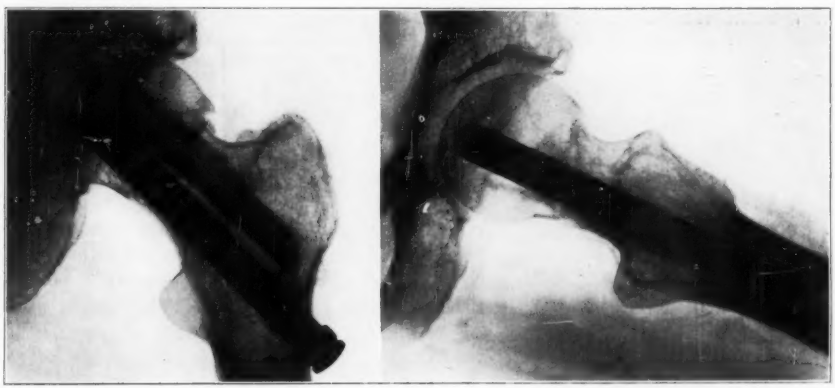

FIG. 3-A FIG. 3-B

Case 40. Roentgenograms show healthy appearance of bone, three months after operation.

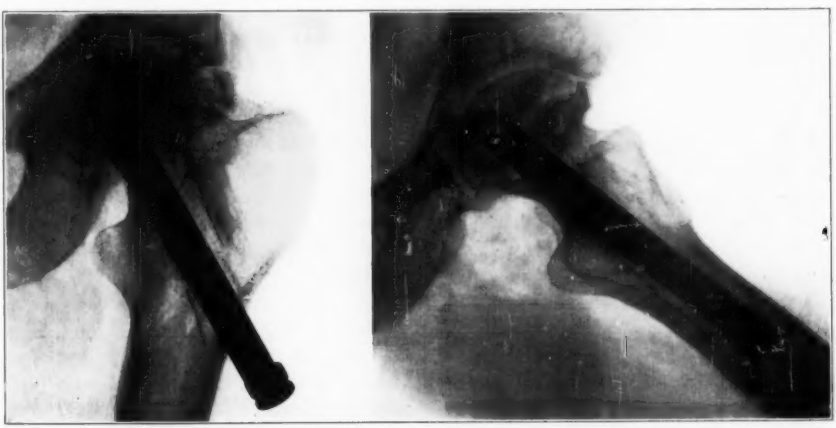

FIG. 3-C FIG. 3-D

Same case, three years after operation, showing typical aseptic necrosis.

FIG. 4-A

FIG. 4-B

Figs. 4-A and 4-B: Case 41. Roentgenograms show healthy appearance of bone, three months after operation.

Fig. 4-C: Same case three years after operation, showing aseptic necrosis. This patient bore no weight on the limb for seventeen months after operation and has never borne his full weight on it.

FIG. 4-C

and hip-flexion exercises. The addition of the graft extends the operation time by only a few minutes.

Subsequent treatment follows the generally accepted principles of early joint movement and absence of weight bearing on the injured extremity for three or four months. The patient is usually allowed to get about on crutches from the fifth day onward. Some oedema of the ankle is usual and is controlled by the wearing of an elastic stocking for six months.

RESULTS

When a fibular graft is combined with a nail, bony union is generally established within six months. Aseptic necrosis, however, may not appear until after the first year has elapsed, and evidence of osteo-arthritis from other causes may not be found until well after the first year. It was considered, therefore, that a two-year follow-up should be accepted as the minimum period in assessing results.

Of the 107 cases, sixty-three were done two years or more ago, five patients being operated on three months or more after the injury. Death due to operation and to natural causes reduced the number of two-year follow-up cases to forty-seven, and it is on this small series that the results are based (Table I).

Mortality

The mortality of 8 per cent. was accounted for mainly by operation being done on patients in poor condition, whose chances of survival without pinning were slight (Cases 58 to 62, Table II). Compared with other published figures, the addition of the graft does not appear to affect the mortality adversely.

FIG. 5-A FIG. 5-B

Case 32. Roentgenograms taken soon after operation show graft just reaching joint line.

Non-Union

Non-union occurred in 13 per cent. (Cases 42 to 47). Two patients fell within three weeks of operation and broke the nail and graft out of the head. In a third patient, infection developed in the wound after an attack of postoperative delirium in which she removed the dressing and several stitches. In two cases the nail and graft were placed too far forward in the head, owing to difficulty in getting a satisfactory lateral roentgenogram during the operation; the nail and graft broke out of the head within ten days. The fracture in the sixth case could not be properly reduced in spite of every manoeuvre (Fig. 2), and union failed to occur.

Thus all cases of non-union were accounted for by accident or by errors of technique. Among the forty-one cases in which union did occur were five cases of previous non-union, although one patient (Case 48) died one year after operation.

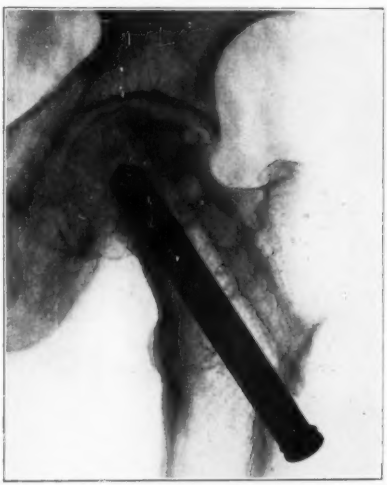

FIG. 5-C

Same case, four years after operation, showing slight osteo-arthritic changes where graft touches joint.

Aseptic Necrosis

Aseptic necrosis developed in four patients (Cases 38 to 41), in all of whom bony union had occurred. As in other series reported, most of the cases were below the average age (fifty-eight, seventy, sixty-four, and thirty-nine years, respectively).

In two of the patients, necrosis developed within one year of operation and progressed to typical collapse of the head and osteo-arthritis (Figs. 3-A to 3-D). The third patient had roentgenographic evidence of aseptic necrosis at fifteen months, but even four years after operation he complained of only mild osteo-arthritic symptoms and had only slight deformity of the head.

TABLE I

RESULTS OF TREATMENT OF INTRACAPSULAR FRACTURES WITH A COMBINED NAIL AND FIBULAR GRAFT

Total number of cases		63
Died in hospital following operation	5 (7.9 per cent.)	
Died within two years from natural causes	10	
Untraced	1	
	16	
Number of two-year follow-up cases		47
Bony union	41 (87.2 per cent.)	
Non-union	6 (12.8 per cent.)	
Aseptic necrosis	4 (8.5 per cent.)	
Osteo-arthritis due to graft penetrating joint	10 (21.3 per cent.)	

The fourth case (Case 41) was of special interest. The patient was a tall man, aged thirty-nine, who had been thrown downstairs and had sustained an intracapsular fracture; this was fixed with a nail and a graft (Figs. 4-A and 4-B). At the end of four months

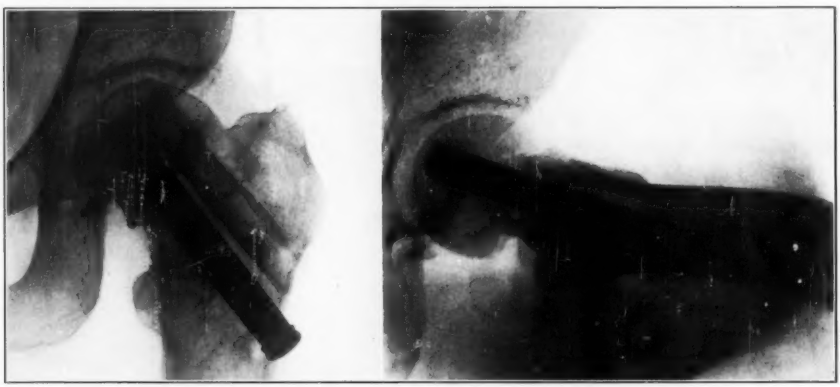

FIG. 6-A FIG. 6-B

Recent case (not in the series reviewed), showing position of nail and graft just after operation.

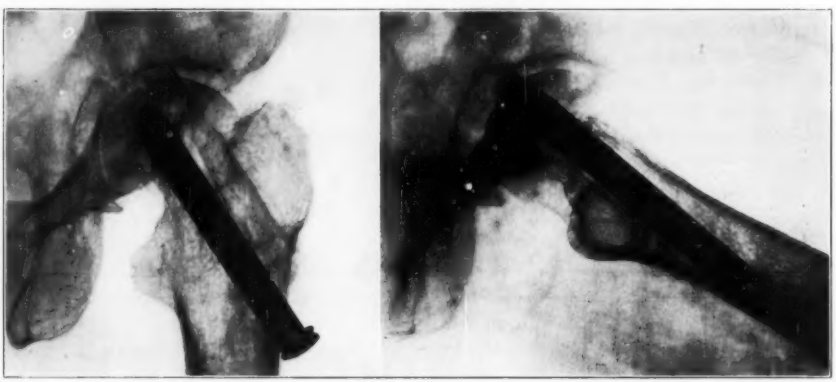

FIG. 6-C FIG. 6-D

Same case three months after operation. The patient had practised weight-bearing three weeks after operation, and impaction of the fracture occurred. The graft penetrated into the joint while the nail, on the other hand, was extruded.

TABLE II

DATA IN SIXTY-THREE CONSECUTIVE CASES OF INTRACAPSULAR FRACTURE TREATED WITH A TRIFIN NAIL AND FIBULAR GRAFT

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
1	62 F.	4 days	3	6	Full		
2	55 F.	35 days	3	6	Full		Graft placed below nail.
3	73 M.	3 days	3	5	20° limitation of flexion; rotation 30% of normal		Mass of callus formed around fracture.
4	63 F.	3 months	4	5	Full		
5	74 F.	9 days	3	5	Full		Nail inserted ¼ inch too far at operation and withdrawn.
6	55 F.	35 days	3	5	Full		
7	61 F.	6 days	3	5	Full		
8	73 F.	1 day	3	5	Full		
9	64 F.	3 days	3	4	Full		
10	65 M.	16 days	3	4	Full		
11	42 F.	7 days	8	4	Full		
12	56 F.	13 days	3	4	Full		
13	72 M.	3 days	3	4	Full		Had below-the-knee amputation in same extremity.
14	67 F.	3 days	3	4	Full		
15	70 F.	4 days	3	4	Full		
16	54 F.	2 days	3	4	Full		Seen in own home. Very nervous and refused to come for final x-ray. X-ray 2 years after operation showed union and no complications.
17	73 F.	4 days	3	3	Full		
18	74 F.	1 day	4	3	Full		Died of cerebral thrombosis, 4 years after operation.
19	52 F.	4 days	3	3	Full		

(*Continued on page 74*)

TABLE II (*Continued*)

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
20	67 M.	6 months	3	3	Full		Treated initially as impacted fracture, but no union after 6 months.
21	67 M.	50 days	3	3	Full		
22	75 F.	4 days	3	2½	Full		
23	87 F.	5 days	3	2	Full		Died 26 months after operation.
24	81 F.	10 days	3	2	Full		
25	62 F.	3 days	3	2	Full		Pin extruded at 6 months and was removed.
26	71 F.	4 days	3	2	Full		Died from pneumonia, 2½ years after operation.
27	64 F.	5 days	3	2	Full		Died from coronary thrombosis, 3 years after operation.
28	38 M.	8 months	4	6	20° limitation of flexion; rotation nil	Osteoarthritis	Graft inserted to joint line. Osteoarthritis developed in fourth year. No aseptic necrosis. Still works as a miner.
29	56 F.	2 days	3	5	Full flexion; internal rotation limited	Osteoarthritis	Slight localized osteo-arthritis developed in upper part of joint in fifth year, due to graft being inserted to joint line.
30	59 M.	8 days	3	4	30° limitation of flexion; rotation nil	Osteoarthritis	Osteo-arthritis where graft reached joint line. Slight limp, but working as laborer.
31	70 M.	5 days	3	4	90° of flexion; no internal rotation	Osteoarthritis	Graft inserted up to joint. Arthritis developed in this area. Has to use a stick.
32	58 F.	45 days	3	4	Flexion full; rotation 30% of normal	Osteoarthritis	Slight osteo-arthritis due to graft just reaching joint. No limp. Slight stiffness after sitting.

(*Continued on page 75*)

TABLE II (*Continued*)

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
33	55 F.	4 months	3	3	Flexion full; slight limitation of internal rotation	? Osteo-arthritis	Doubtful area of osteo-arthritis where graft just reaches joint. No symptoms.
34	59 F.	4 days	3	3	Flexion full; rotation 30% of normal	Osteo-arthritis	Graft just reaches joint. No disability. X-ray changes slight.
35	73 F.	3 days	¼	2½	30° limitation of flexion; rotation 30% of normal	Osteo-arthritis	Graft just reached joint. Local osteo-arthritis developed. Graft broke but union occurred. No limp.
36	70 M.	9 days	3	2½	Flexion full; rotation nil	Osteo-arthritis	Graft inserted to joint, causing osteo-arthritis. Symptoms slight. No limp.
37	60 F.	5 days	3	2	40° limitation of flexion; rotation 30% of normal	Osteo-arthritis	Graft inserted to joint line. Symptoms of arthritis mild.
38	58 F.	9 weeks	5	4	Flexion to right angle; no rotation	Aseptic necrosis	Had Paget's disease of tibia and fibula of same limb. Graft removed from other leg. Necrosis first observed in eleventh month. Collapse of head and osteo-arthritis followed.
39	70 F.	5 days	3	4	Full flexion; rotation 30% of normal	Aseptic necrosis	Slight limp; uses stick when outside. Necrosis first noticed at 15 months. No collapse of head.
40	64 F.	6 days	3	4	45° range of flexion; no rotation	Aseptic necrosis	Necrosis first observed at 7 months. Collapse of head and osteo-arthritis followed.
41	39 M.	2 days	17	3	All movements extremely limited	Aseptic necrosis	Did not bear weight for 17 months. Necrosis first observed about 21 months.
42	76 F.	7 days		5	90° range of flexion	Non-union	Fell and broke nail and graft out of head in third week.

(*Continued on page 76*)

TABLE II (*Continued*)

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
43	39 F.	2 days	3	5	90° range of flexion	Non-union	Poor reduction, owing to interlocking of fragments. Subtrochanteric osteotomy done.
44	72 F.	3 days		1	60° range of flexion	Non-union	Fell and broke nail and graft out of head in third week. Subtrochanteric osteotomy done.
45	67 F.	3 days	9	3½	30° range of flexion	Non-union	Dressings torn off in postoperative delirium. Fracture became infected. Pin extracted.
46	69 F.	6 days		2½	60° range of flexion	Non-union	Pin and graft placed too far anteriorly in head and broke out. Subtrochanteric osteotomy done.
47	74 F.	14 days		2	30° range of flexion	Non-union	Pin and graft placed too far anteriorly in head and broke out. Patient never left bed after operation. Died of heart failure 2½ years later.
48	60 F.	1 year	3	9 months	20° limitation of flexion		Died one year later, following operation for pituitary adenoma. Had no pain or limp in extremity.
49	71 F.	3 days	3		Full flexion; rotation 50% of normal		Died 15 weeks after operation. Oedema of both legs developed. Heart failure.
50	69 M.	6 days	3	19 months	Full		Died 20 months after operation from cerebral thrombosis. Had thrombosis in limb after operation.
51	76 M.	3 days	3	3 months	Full		Died 4 months after operation from a stroke.

(*Continued on page 77*)

TABLE II (*Continued*)

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
52	70 F.	3 days	3	4 months	Full		Mental symptoms developed; attempted suicide; admitted to mental hospital. Died at fifth month.
53	69 M.	3 days	3	7 months	Flexion full; rotation 50% of normal		Walked normally. Died from stroke, 10 months after operation.
54	70 F.	3 days	3	3 months	Full		Died 3½ months after operation from acute obstruction, due to carcinoma of colon.
55	74 M.	15 days	3	4 months	Flexion full; rotation 30% of normal		Died 5 months after operation from retention of urine and uraemia.
56	70 F.	6 days	3	14 months	Full		Died 15 months after operation. Cause of death not ascertained. No limp or pain.
57	78 F.	5 days	2	2 months	Full		Died at home, 3 months after operation, from pneumonia. Walked a little without help.
58	84 M.	10 days			Full flexion	Died	Died 7 weeks after operation, from pneumonia.
59	73 M.	5 days				Died	Died day following operation. Poor risk; had fever and slight delirium before operation. Operation delayed for 3 days.
60	69 F.	2 days				Died	Feeble; poor risk. Died 4 days after operation.
61	65 M.	19 days				Died	Had râles in chest before operation. Died day after operation.
62	71 F.	30 days				Died	Never left bed. Died from uraemia, 2 months after operation.
63	83 F.	5 days					Could not be traced after leaving hospital.

of non-weight-bearing he had full joint movements and was free from pain. Owing to the development of a psychological factor, however, he could not be persuaded to put his foot to the ground; and he continued to walk with crutches and did not bear weight on the injured limb until seventeen months after the operation. In spite of this long period of freedom from weight-bearing, aseptic necrosis developed, clinically and roentgenographically, toward the end of the second year, and it eventually progressed to marked osteo-arthritis of the joint. At no time did he bear full weight on the limb and, therefore, very little collapse of the head occurred (Fig. 4-C).

Thus aseptic necrosis developed in only 9 per cent. of the cases as compared with 30 per cent. in a large series of 365 cases, reviewed by Per Linton, in which treatment was by a nail alone.

Osteo-Arthritis

Apart from cases of aseptic necrosis, osteo-arthritis occurred in 21 per cent. (Cases 28 to 37) and was due to the graft penetrating the joint. In these cases the graft was inserted rather close to the joint (Figs. 5-A, 5-B, and 5-C). It was not realized at the time that the usual roentgenograms in two planes might give only an approximate indication of the relation of the end of the nail and the graft to the joint, and subsequent roentgenograms showed that the graft had just penetrated the joint. In these cases, osteo-arthritic symptoms developed two or three years after operation, but in only two cases did the arthritis prove more than a minor disability. This penetration of the graft into the joint may also occur, if early weight-bearing and consequent further impaction take place (Figs. 6-A to 6-D). The living graft fuses more rapidly to the vascular basal fragment than to the head, and so tends to pass in toward the joint. The inert nail, remaining more firmly embedded in the relatively avascular head, tends usually to be extruded. To avoid penetration of the fibular graft into the joint, it should be inserted to a depth of about one-quarter inch less than the nail.

In no case was there any complaint of ankle weakness in spite of the fact that, in most, no regeneration of the fibula had occurred.

SUMMARY AND CONCLUSIONS

In the treatment of intracapsular fractures, the use of a fibular graft with a trifin nail does not increase the mortality, and the addition of the graft lengthens the operation time by only a few minutes.

In this small series of cases a much higher proportion of bony union occurred (87 per cent.) and fewer cases of aseptic necrosis appeared (9 per cent.) as compared with the published results of cases treated with a nail alone. The true figure for aseptic necrosis, however, can only be assessed after a clinical and roentgenographic follow-up of all the cases for a number of years; and the author's series of cases is too small to draw any hard-and-fast conclusions on this aspect of the condition.

In one patient, necrosis developed in spite of seventeen months of non-weight-bearing. It is evident that non-weight-bearing does not prevent necrosis, although, of course, it may minimize collapse of the head and be of some value in delaying the onset of osteo-arthritis. Early weight-bearing may result in further impaction and shortening of the neck and this may cause the graft to penetrate the joint. For this reason weight-bearing should be avoided for the first three months, and the fibular graft should be inserted a little less than the depth of the trifin nail.

The results in this small series of cases would seem to justify the use of a combined nail and fibular graft in all intracapsular fractures of the femur.

REFERENCES

DICKSON, J. A.: Treatment of Ununited Fractures of the Neck of the Femur by Means of Bone Graft and Smith-Petersen Nail. Surg. Clin. North America, **19**: 1235–1241, 1939.

EYRE-BROOK, A. L., and PRIDIE, K. H.: Intracapsular Fractures of the Neck of the Femur. Final Results of 75 Consecutive Cases Treated by the Closed Method of Pinning. British J. Surg., **29:** 115–138, 1941.

FRACTURE COMMITTEE, AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS: Treatment of Fractures of the Neck of the Femur by Internal Fixation. J. Bone and Joint Surg., **23:** 386–390, Apr. 1941.

GALLIE, W. E., and LEWIS, F. I.: Ununited Fracture of the Neck of the Femur in the Aged. J. Bone and Joint Surg., **22:** 76–80, Jan. 1940.

HENDERSON, M. S., and HENDERSON, E. D.: Bone Grafts for Ununited Fracture of the Neck of the Femur. A Report of Ninety Cases. J. Internat. Coll. Surg., **9:** 26–34, 1946.

INCLÁN, ALBERTO: Late Complications in Fracture of the Neck of the Femur Treated by Nailing, Bone Grafting or Both. J. Internat. Coll. Surg., **9:** 36–50, 1946.

KING, THOMAS: The Closed Operation for Intracapsular Fracture of the Neck of the Femur. Final Results in Recent and Old Cases. British J. Surg., **26:** 721–748, 1939.

LINTON, PER: On the Different Types of Intracapsular Fractures of the Femoral Neck. A Surgical Investigation of the Origin, Treatment, Prognosis and Complications in 365 Cases. Acta Chir. Scandinavica, **90:** Supplementum 86, 1944.

SMITH-PETERSEN, M. N.: Treatment of Fractures of the Neck of the Femur by Internal Fixation. Surg., Gynec., and Obstet., **64:** 287–294, 1937.

WARDLE, E. N.: Subcapital Fractures of Femoral Neck. Fixation by Pin and Graft. Lancet, **1:** 399–402, 1945.

DISCUSSION

MR. H. JACKSON BURROWS, LONDON, ENGLAND: It is at once a privilege and an embarrassment to follow the giants. In particular, it is hardly possible to speak of aseptic necrosis without using the name of Phemister. Dr. Phemister made known the concept of creeping substitution, and he has also demonstrated the fragility of the bone in the zone of replacement. Dr. Compere has reminded us how slowly cortical bone undergoes substitution. This emphasizes the importance, when we are dealing with fractures of the long bones, of avoiding further damage, not only by proper handling of the injured limb, but also by avoiding unnecessary or unnecessarily extensive cutting operations when closed manipulation would suffice, or, conversely, fruitless closed manipulations when open operation would be less damaging.

In aseptic necrosis of the femoral head a further complication arises,—namely, the proximity of a joint; and the evils of aseptic necrosis depend not merely upon the changes in the bone, but also upon the destruction of the articular cartilage. For this we can do virtually nothing. The ingenious operations which we have heard described will hasten repair of bone, but they can do little or nothing for the articular cartilage. It is in prevention that we must seek salvation.

Gentleness in reduction of congenital dislocation of the hip is universally accepted. In slipping of the upper femoral epiphysis, the devastating sequel of forcible manipulation in some cases was first demonstrated by my late chief, Elmslie. We are perhaps slow in learning the same lesson in fractures of the femoral neck. Most, though not all, can be reduced by gradual weight traction, followed by very little subsequent manipulation,—mere medial rotation. Delay is not hazardous if preoperative management is understood.

DR. ROBERT W. JOHNSON, BALTIMORE, MARYLAND: I want to congratulate the Program Committee on their arrangement of this Symposium, because they have given us a well-rounded picture of the whole problem. Each of the essayists has added a definite contribution which is different from the others. For that reason I would like to discuss briefly each one.

Dr. Compere I want to thank for the clinical confirmation and application of the experimental work which I presented as a thesis to this organization some twenty years ago. I had begun to believe it had been forgotten. There is, however, a note of hope that I would like to add to his statement that much of the bone in the region of a badly comminuted fracture is non-viable. From subsequent studies in new bone and the formation of callus, I believe that the viability of bone cells in the comminuted fragments *in loco* is not of particular importance. The ingrowing vessels coming to organize the blood clot bring with them embryonic fibroblasts, which are quite capable of assuming the whole job of new-bone formation. The old bone acts as a suitable scaffolding for this work.

Dr. Phemister, as usual, has presented his surgical thesis, backed up by beautiful physiological and pathological data. I could not, however, follow him quite to the end of his argument that the implantation of more dead bone—namely, the graft—in the head of the femur is actually going to prevent aseptic necrosis. I believe that drilling of a rather large open tract will do more for vascularity than a graft, although it does not in any way take over the mechanical function of support of the region during the healing period. It is simply a physiological rather than a mechanical argument.

Mr. Patrick has taken up the question where Dr. Phemister left it, using a pin and graft in the acute fracture of the hip. He has certainly shown encouraging and helpful results. However, his follow-up is necessarily, in my opinion, too short to permit disposing of the problem of aseptic necrosis in the same manner as Dr. Phemister has done, whose last case had a follow-up of seven and one-half years.

These papers have given us a beautiful presentation of fracture of the neck of the femur and its problems, and what we should now know about them.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: I would like to mention a type of necrosis that I have seen many times. In operating for osteomyelitis years after the acute disease, one may find layer after layer of dead bone which is completely surrounded by living bone. That bone will stay there for many years before it is absorbed. A similar necrosis may occur at the ends of the fracture fragments, and this may be one cause of non-union.

DR. DALLAS B. PHEMISTER (closing): Mr. Burrows spoke of the necrotic articular cartilage. It may persist for years in regions inaccessible to the invading blood vessels and connective tissue; but they may reach it along the surface or by growing through the underlying dead bone, and replace it by fibrocartilage. Extending the drill holes through the cartilage hastens the invasion and replacement. This should be beneficial, since Albert Key has shown experimentally that chipping off a fragment of articular cartilage and bone and leaving it in the joint favors the development of degenerative arthritis.

As to the strong tibial bone grafts employed, I believe they are valuable in that they favor the union of the fracture, when present; and, placed in the upper portion of the dead head, they protect it against collapse, which is the worst of complications, while invasion and transformation into new bone are taking place.

There is great difference of opinion as to when the bone dies in these cases of disturbance of its circulation by injury or occlusion. I have studied microscopically between fifty and seventy-five femoral heads, removed either at operation or at necropsy, performed somewhere between a few days and fifteen or twenty years after the onset of the trouble. The evidence has been that the bone always dies soon after the accident or onset of the disease which cuts off the circulation. One must distinguish between the time when the bone dies and the time when this necrosis can be recognized clinically and roentgenographically. Microscopic examination of specimens removed early shows that the bone dies soon after the circulation has been cut off. Sections of older specimens show only the later changes. However, months or, when the fracture has united, even one or two years may elapse before changes take place, such as atrophy of the adjacent living bone, creeping substitution, collapse, and arthritis, which make it possible to diagnose the condition clinically and roentgenographically. It is a common error to assume that the bone dies at this late date and not at the onset of the trouble.

MR. JAMES PATRICK (closing): I would like to comment on a case which throws some light on the viability of the head. You will remember that I said one has to be careful not to put the graft too close to the articular surface of the head, for the usual roentgenograms taken in two planes do not always give a true picture of the proximity of the graft to the joint.

Another factor sometimes appears. There is a tendency for the graft subsequently to move in toward the joint. A case was illustrated in which the patient did not follow her instructions about non-weight-bearing and did not report until four months after leaving the hospital. During this period of early weight-bearing, some collapse and impaction of the neck had occurred. The pin, by reason of its physical pressure on the bone into which it had been driven, caused some reaction and absorption of the bone. This occurred to a greater extent in the vascular basal fragment than in the head, and so the pin was extruded when the collapse of the neck occurred. The graft, however, although perhaps regarded as dead tissue by some, is certainly not so dead as the nail. Fusion of the graft to the relatively avascular head takes longer than fusion to the basal fragment, and so, when collapse of the neck occurred, the graft moved into the head and penetrated the joint. I think this contrary shift of the nail and graft throws some light on the state of viability of the head, and indicates the need for caution in placing the graft.

My figures of the incidence of aseptic necrosis, when a graft is used with the nail, confirm Dr. Phemister's observations; and my preference for the fibula instead of the dense cortical bone of the tibia as a source of material for a graft is supported by Dr. Compere's investigations.

A METHOD OF SUBTROCHANTERIC LIMB SHORTENING *

BY LAWSON THORNTON, M.D., ATLANTA, GEORGIA

Since the introduction of treatment of trochanteric fractures by internal fixation, procedures have been developed and reported by a number of surgeons. Blount's method has been the most outstanding in trochanteric shortening, and White's in shortening the shaft of the femur.

The object of this presentation is to show a method, developed more recently, which provides, before the osteotomy is done, for preservation of the normal angle between the femoral shaft and the neck. The method differs from others only in detail and in the use of a different design of instrument for internal fixation. The normal anatomical relationship of the trochanter and the shaft is maintained by this procedure. No external fixation is applied.

By following the details as presented here, plus the use of the specially designed trochanteric plate and Smith-Petersen nail†, an accurate procedure may be carried out. In the author's experience over a number of years, this plate and nail have always remained intact and the connecting screw has always held.

The technique is essentially that used in treatment of trochanteric fractures. The upper third of the shaft of the femur and the trochanter are exposed by a lateral incision. First, the Smith-Petersen nail is driven at the proper angle to make the plate fit along the lateral surface of the shaft and to maintain the normal angle between the femoral shaft and neck. In order to accomplish this accurately, a guide is necessary (Fig. 1).

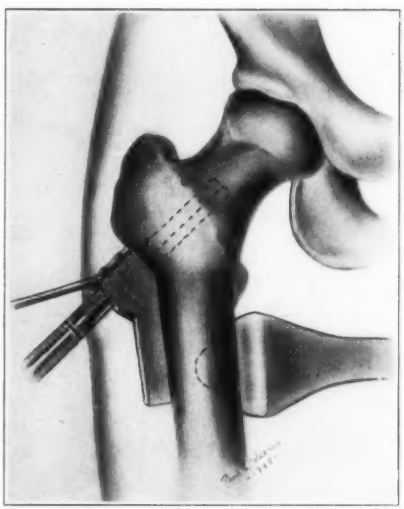

FIG. 1

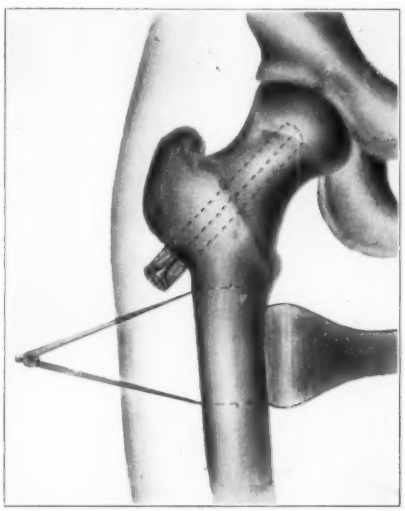

FIG. 2

Fig. 1: Guide for driving Smith-Petersen nail.

Fig. 2: Section of bone to be excised has been measured with calipers. Saw cut indicates where fragments are to be set.

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

† Trochanteric plates of faulty design have been placed on the market, which may be expected to become disconnected or to break or bend.

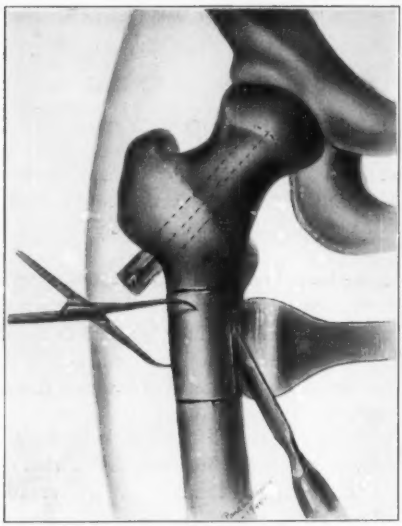

FIG. 3

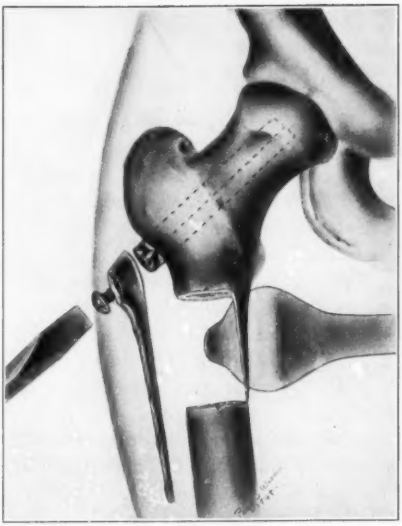

FIG. 4

Fig. 3: Shows method of cutting bone.
Fig. 4: Plate is about to be attached to nail. Later, just before closure of incision, the connecting screw should be tightened forcibly with a large screw driver. Note flange of bone which has been retained.

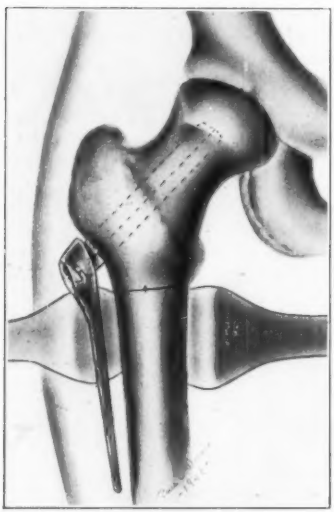

FIG. 5

Fragments have been aligned.

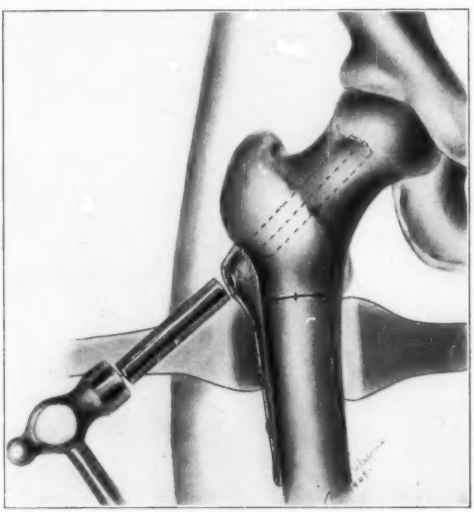

FIG. 6

The nail has been driven in completely.

About one-half inch of the nail is left protruding, so that later the plate and screw may be attached. The use of several Baer-Bennett retractors gives adequate exposure of bone and prevents soft-tissue damage by saw and chisel. The section of bone to be excised is measured with calipers. A saw cut, along the cortex of the bone, constitutes a marker to be used in setting the fragments without abnormal rotation (Fig. 2).

Either a broad, sharp chisel or a broad motor saw, or both, may be used for cutting

the bone (Fig. 3). Since the trochanteric portion of the femur is broader than the shaft, the bone may be carved so as to leave a flange of bone extending down along the medial

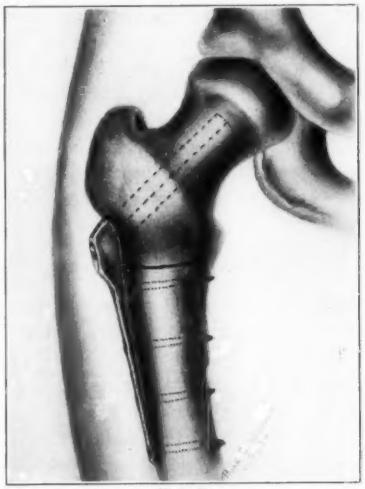

FIG. 7

Fig. 7: The plate has been fastened to the femoral shaft so that the screws engage both cortices.

Fig. 8: Case 1. After left subtrochanteric shortening.

FIG. 8

FIG. 9

Case 2. Roentgenogram of left femur after shortening.

FIG. 10

Case 3. Two-inch shortening of right femur.

cortex. This flange makes the setting easier and is helpful in fixation and in obtaining bony union.

Before the fragments are set, the plate is attached to the nail (Fig. 4). The fragments, which have been freely exposed subperiosteally, are brought into apposition, and the saw cuts are matched (Fig. 5).

Driving the nail is then completed (Fig. 6) and the plate is fastened to the femoral shaft by screws which penetrate both cortices (Fig. 7). The last and most important detail is that the connecting screw be tightened forcibly. A large screw driver is used.

Convalescence is the same as that following a trochanteric fracture. No external fixation, suspension, or traction is used. The usual postoperative nursing care is required, the leg being kept comfortable on a pillow and opiates being administered as needed during the first few days.

When the period of discomfort has passed, the patient gradually increases independent activities and has freedom of the bed. Reasonable care is advised until there is union at the site of the osteotomy. Callus formation, as shown by roentgenogram, is helpful in determining the progress toward full weight-bearing. Ten or twelve weeks in bed are recommended, followed by walking with crutches and gradually increasing weight-bearing. Physical therapy is helpful for the muscles of the shortened extremity. Training and development of the habit of walking in a natural way add much to the end result.

Removal of the metal used for fixation is desirable at some future date.

DISCUSSION

Considerable responsibility is associated with surgery for shortening the normal lower extremity, and this responsibility must be shared by the surgeon as well as by the patient and his family. The surgeon's experience and results with internal fixation of trochanteric fractures may be the deciding factor.

CASE REPORTS

Case 1. E. M., an eighteen-year-old girl, had one and one-half inches of shortening of her right femur as a result of old healed osteomyelitis of the upper portion of the femur, involving the upper femoral epiphysis, the head, and the acetabulum. On March 5, 1945, she was referred by the author to Dr. Smith-Petersen for arthroplasty. An excellent result was obtained. Because of the inequality in limb length of one and one-half inches, her gait was not in keeping with such a good hip.

On June 26, a lift of one and one-half inches was put under her right foot and roentgenograms were taken. (This amount of elevation was needed to square the pelvis and make the spine straight, but the shortening required would be one and three-eighths inches.) On June 29, with pentothal anaesthesia, subtrochanteric shortening of one and three-eighths inches was done on the left lower extremity, at the Piedmont Hospital. A Smith-Petersen nail and the plate illustrated were used (Fig. 8).

After four weeks, the patient left the Hospital. Roentgenograms, taken on September 5, showed evidence of union at the site of osteotomy, but not sufficient to permit her to be up. By October 23, she was able to bear weight without crutches, and roentgenograms on December 4 showed solid union.

On July 10, 1946, under general anaesthesia, the nail and plate were removed. The patient remained in the Hospital for one week, and the sutures were removed after she went home, on July 22.

When last seen, on January 29, 1948, this patient was walking well and was about to be married.

Case 2. C. H. was a seventeen-year-old girl, who had had pyogenic disease of the right hip when she was seven years old. The femoral head had become necrotic and sequestrated. The infection had cleared, leaving fibrous ankylosis with adduction-flexion deformity. Later a hip fusion was done, followed by subtrochanteric osteotomy for correction of the adduction-flexion deformity.

There was one and one-half inches of shortening by measurement; this shortening was also determined by placing enough blocks under the right foot to equalize the length. In addition, a cork lift of one and one-half inches was added to the sole of the right shoe, and the patient found after several days' trial that this was the amount needed to equalize the length of her extremities.

On March 19, 1947, at the Piedmont Hospital, the trochanter and upper femoral shaft on the left were exposed by the usual lateral approach. A segment, one and one-quarter inches long, was removed, leaving a distally projecting tongue on the medial aspect of the proximal fragment. The distal fragment was fitted into this notch against the proximal fragment and was fixed in place with a Smith-Petersen nail, plate, and

screws (Fig. 9). A little space was noted anteriorly in the fitting of the fragment, but the joining was tight posteriorly and the anterior space was filled with cancellous bone. The wound was closed as usual, and an elastic-bandage spica was applied. A blood transfusion was given during the procedure and the patient returned to her room in satisfactory condition. Penicillin was administered postoperatively and continued for five days.

On April 24, roentgenograms showed excellent position and fixation with some early callus. The postoperative course was satisfactory and the patient was discharged from the Hospital on May 7. Approximately three weeks later she began walking with the aid of crutches. Roentgenograms on June 16 showed union at the site of the osteotomy. By September 1 she was walking well and had no discomfort.

In May 1948, the plate, nail, and screws were removed. The incision healed by first intention.

CASE 3. A. M. F., a girl, nineteen years old, had had pyogenic disease of the left hip, which healed with solid bony fusion plus adduction-flexion deformity. She walked with a four-inch lift on her left shoe. After subtrochanteric osteotomy for correction of 20 degrees of adduction and 20 degrees of flexion deformity, there remained two inches of difference in the length of the lower extremities.

On March 14, 1947, at the Piedmont Hospital, a femoral shortening of two inches was carried out. By a lateral incision, the trochanter and upper shaft of the right femur were exposed, and a two-inch segment was removed from just below the greater trochanter. A medial tongue was left on the proximal fragment, and the fragments were accurately approximated. Fixation was by a Smith-Petersen nail plus plate and screws, the proximal screw engaging the proximal and distal fragments. The wound was closed in layers, and the usual dressing with an elastic-bandage spica was applied. A blood transfusion was given during the operation. The patient had no unfavorable reaction (Fig. 10).

On March 31, the wound had healed *per primam* and the sutures were removed. The patient was discharged from the Hospital, but was cautioned not to begin weight-bearing until roentgenograms had been taken, at the end of three months. When seen on October 21, she was walking well with only slight lameness.

SUMMARY

It is suggested that this plan for subtrochanteric shortening of the lower extremity may have the following advantages:

1. Before the osteotomy is done, provision is made for maintaining the normal angle between the shaft and the trochanter.
2. No external fixation is used.
3. The trochanteric flange adds strength, stability, and bone contact, in addition to being helpful in the setting.

REFERENCES

BLOUNT, W. P.: Blade-Plate Internal Fixation for High Femoral Osteotomies. J. Bone and Joint Surg., **25**: 319–339, Apr. 1943.

MOORE, A. T.: Blade-Plate Internal Fixation for Intertrochanteric Fractures. J. Bone and Joint Surg., **26**: 52–62, Jan. 1944.

THORNTON, LAWSON: The Treatment of Trochanteric Fractures of the Femur: Two New Methods. Piedmont Hosp. Bull., **10**: 21–27, 1937.

Treatment of Traumatic Conditions of the Hip. *In* Lectures on Regional Orthopaedic Surgery and Fundamental Orthopaedic Problems, American Academy of Orthopaedic Surgeons, pp. 45–54. Ann Arbor, Michigan, J. W. Edwards, 1947.

WHITE, J. W.: Overlapping Procedure for Shortening Bone Defects Course. *In* Lectures on Reconstruction Surgery, American Academy of Orthopaedic Surgeons, pp. 48–50. Ann Arbor, Michigan, Edwards Brothers, Inc., 1944.

DISCUSSION

DR. WALTER P. BLOUNT, MILWAUKEE, WISCONSIN: The paper which Dr. Thornton has so beautifully and so modestly presented illustrates an excellent method of shortening the lower extremity. There is no need for him to go into the indications; we all know them. The question is: "What is the best method of equalizing limb length after growth has stopped?"

To shorten a femur in the middle third is an operation of considerable magnitude. It carries greater risk of deformity, such as bowing or angulation of the shaft, than an operation at the proximal end. I noticed no complications in Dr. Thornton's cases, and there is no reason why there should be any. Operation in the middle third requires a cast in most instances. There is sometimes delay in union, which is not so likely where the bone has been cut in the more vascular proximal portion. There is no question about the distal third: I think that no one would attempt the operation there.

I have used a method very similar to the method just shown, which was suggested to me by Hugh Smith in 1943. I have tried it out in various conditions and used it for different degrees of shortening. I have used a

blade-plate, a modification of Austin Moore's plate, instead of Dr. Thornton's appliance. Dr. Farill, who is here, and I conceived this idea of internal fixation of an osteotomy independently. In one case, with one and one-quarter inches of shortening, good progress was made because the boy was fifteen. Five months later there was solid union. After fourteen months of fixation the device was removed and the hip was nearly normal. I do not know whether or not it is necessary to take out the fixation device. In older patients and with inert metal, it is not necessary. In the boy just described, I took it out.

The danger in older patients is chiefly that of delayed union. Dr. Thornton left a tongue of bone on the proximal fragment. I did that in one case, but it did not prevent delayed union. I have done eight cases, with delayed union in one and non-union in one. I urge the use of additional bone from the site or from the bone bank to ensure union.

I mentioned only eight cases because in Wisconsin, at least, we do not often have to shorten the lower extremity. We arrest growth in time by the excellent method of Dr. Phemister or by stapling the epiphyses, and rarely do we have patients with very unequal limb length.

It seems significant that this paper was presented immediately after the ones on avascular necrosis. I should urge that care be taken not to produce too much trauma, because of the danger of this complication. We all know that it may occur in intertrochanteric fractures. It would be too bad to *produce* a fracture below the hip in a patient from eight to fifteen years of age and to obtain avascular necrosis.

Another possibility is the use of the Küntscher nail as internal fixation in the shortening operation. Dr. Carpenter and his co-workers recently demonstrated this beautifully. I rather think that Dr. Thornton's method and my method may be supplanted in the near future by the use of the Küntscher nail.

DR. J. WARREN WHITE, GREENVILLE, SOUTH CAROLINA: I appreciate Dr. Thornton's bringing this method to our attention. It is an excellent way of doing shortening of the femur and I am using it in selected cases, but I still feel that shortening in the middle third is the method of choice. This contribution, I think, has great value in those cases where you have to do more shortening than is possible in the middle third. There is a certain amount of difficulty in closing the wound when more than two inches of shortening are done in the middle third. This subtrochanteric shortening is of particular value in those patients having bulky thighs, for the closure is much easier, owing to the relative difference in the amount of soft tissue present.

I wish that more people would consider shortening in the middle third. I have done a great many such operations, without the mechanical difficulty that I have had with five or six subtrochanteric shortenings. Of these subtrochanteric shortenings, I have had two with delayed union and one with non-union. Of the shortenings in the middle third, I have had no delayed unions or non-unions.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: I have used the subtrochanteric method and I do not like it very well. I shorten the femur in an adult with a good deal of trepidation. I cut the bone with a Gigli saw, which seems to me the easiest method. I think it would be difficult for me to make this tongue as Dr. Thornton has suggested. One should be sure to get the blade or nail-plate in position before cutting the femur. In one instance my Gigli saw cut a little too far and the femur broke before I got the blade or nail-plate into the neck of the femur. I was faced with the troublesome problem of how to overcome the posterior displacement of the distal fragment. Also, after you leave the lesser trochanter you are not dealing with cancellous bone. It takes just as long for it to unite here as in the middle portion of the shaft. Therefore, I am still in a quandary. I think I prefer an oblique or Z-plastic method, with the osteotomy in the lower portion of the femur and internal fixation of the fragments.

DR. LAWSON THORNTON (closing): Subtrochanteric femoral shortening, which was originated by Dr. Blount, has become generally used. The object of this presentation is to show another technique, in which the Smith-Petersen nail plus an especially designed trochanteric plate are employed.

THE USE OF SKELETAL TRACTION IN THE TREATMENT OF FRACTURES OF THE FEMUR *

BY EDWARD M. WINANT, M.D., NEW YORK, N. Y.

During the first years of World War II, compound fractures of the femur resulting from battle injuries were treated, for the most part, by Orr dressings and immobilization in plaster-of-Paris spica splints. In 1944, concurrent with the advent of delayed primary closure of wounds, this treatment was discarded in favor of skeletal traction. It was felt that this change in treatment would result in a better position of the major fracture fragments, maintenance of limb length, and improved knee and ankle motion.

In this study of sixty-eight fractures of the femur which were treated by skeletal traction in an Army General Hospital, traction was accomplished by the use of the Kirschner wire and the extremity was supported in balanced suspension. The Pearson attachment was used in conjunction with the Thomas splint, in order to establish early knee action. Supracondylar traction was preferred to that obtained through the tibial crest. The supracondylar region was selected for the insertion of the Kirschner wire, unless contra-indicated by the presence of a soft-tissue wound involving this region of the thigh or by a fracture of the distal three inches of the femur.

TABLE I

TYPES OF FRACTURES TREATED

	Simple	Compound	Total
Comminuted	1	38	39
Oblique	4	18	22
Transverse	2	5	7
Totals	7	61	68

Supracondylar Traction

Since a difference of opinion exists regarding the choice of site for insertion of the Kirschner wire, the advantages obtained from supracondylar traction will be stressed. The general rule governing the use of skeletal traction—that is, never cross a joint unless necessary—still holds in this instance. If we are seeking skeletal traction, why depend upon the transmission of this traction through the soft tissues of a joint? A protective mechanism is gained from the soft tissues interposed between the skin and femur, which act as a barrier against infection extending from skin to bone. In addition, these soft tissues serve as a cushion, lessening the possibility of skin necrosis from pressure of the wire spreaders. Should pressure necrosis occur with tibial traction, the bone is exposed, thus predisposing to the development of osteomyelitis. Furthermore, if supracondylar traction is utilized in conjunction with knee motion, the mechanical advantages can readily be appreciated. There is no local irritation of the femur resulting from flexion and extension of the tibia, and traction is maintained through the same plane. With tibial traction, on the other hand, the tibia rotates around the Kirschner wire as the knee moves, and the possibility of pressure necrosis is enhanced. The Kirschner wire should be inserted under absolute

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948.

FIG. 1-A

FIG. 1-B

FIG. 1-C

Fig. 1-A: Shows considerable loss of bone substance and of limb length. Soft-tissue destruction is present.
Fig. 1-B: Limb length was gained by skeletal traction, and the position was held until soft-tissue healing permitted internal fixation with metal plate and screws for further stability.
Fig. 1-C: Anteroposterior and lateral roentgenograms, taken five months after bone-grafting with iliac bone and tibial onlay graft to replace lost bone, show solid bony union.

TABLE II

RANGE OF KNEE MOTION

Degree of Motion	Number of Cases
Extension	
Full	61
Satisfactory (175 degrees or more)	7
Flexion	
Full	0
Satisfactory (90 degrees or more)	32
Unsatisfactory (less than 90 degrees)	36

aseptic technique, while the patient is in the operating room. Another measure for the prevention of infection and skin necrosis is the use of at least twelve dressings, four by four inches in size, placed over the end of the Kirschner wire. The innermost dressing should be sealed to the skin by collodion, and the remaining dressings should be held in place by a bandage before the wire spreader is applied. As a result of adherence to these principles, not a single case of infection or pressure necrosis of bone occurred at the wire site.

Skeletal traction was maintained until union of the fracture was solid clinically and roentgenographically, and weight-bearing with brace and crutches was possible. However, the traction was interrupted in practically every case during the course of treatment, since the majority of these patients had their initial treatment overseas and were placed in plaster spicas for the return trip to this country. The average length of time from injury to weight-bearing was 6.1 months.

Types of Fractures

A simple classification of the types of fractures treated (Table I) indicates that sixty-one of the total of sixty-eight were compound fractures. Thirty-nine of the total number were comminuted; seventeen had loss of bone substance. It was impossible to determine whether this loss of bone substance resulted from the original injury or, as suspected in many instances, from too ambitious débridement.

Knee Motion

One of the chief aims of treatment by skeletal traction, plus balanced suspension with the Pearson attachment, was to maintain a good range of knee motion. The range of motion obtained in these cases was disappointing.

FIG. 2-A FIG. 2-B

Anteroposterior and lateral roentgenograms illustrating a case in which anatomical alignment of the fracture fragments was not obtained. However, good bone contact was present and the functional position was considered satisfactory.

The apparatus does not permit full extension, and flexion is possible only to 135 degrees. However, in some knees that could not approach even this limited range of motion, some knee function was maintained; this prevented a fibrous ankylosis which might have developed, had the extremity been immobilized in a circular plaster splint (Figs. 1-A, 1-B, and 1-C). Because it was impossible to obtain a ring lock-knee brace, it was necessary to use a stiff toe-to-groin brace with an ischial ring, which held the knee in full fixed extension. These patients were instructed to remove their braces and to exercise their knees; but, since the majority were granted convalescent furloughs, it is doubtful if the instructions were carried out conscientiously. Consequently, motion was actually lost during this important period of treatment, whereas it would have been gained, had a knee-lock brace been applied to permit motion during non-weight-bearing. These patients were followed for an average of only two and one-half months after weight-bearing had been begun, and the majority were given medical discharges while they were still wearing their braces. The range of knee motion at the time of discharge is shown in Table II.

Limb Length

Full limb length is not always maintained by skeletal traction. With extensively

FIG. 3-A FIG. 3-B FIG. 3-C

Fig. 3-A: Anteroposterior roentgenogram shows malposition and malunion of the fracture fragments, with overriding and poor bone contact.

Figs. 3-B and 3-C: Anteroposterior and lateral views after open reduction and internal fixation with metal plate and screws and onlay tibial bone graft.

comminuted fractures, impaction or shortening from overriding of the major fragments may result in better bone contact than would be obtained in an effort to secure full limb length. While every attempt should be made to maintain limb length, shortening of as much as one inch will not prove to be a serious handicap to the patient. The endeavor to maintain limb length should be tempered with caution, to prevent distraction of the fracture fragments.

The final limb lengths in this series (Table III) indicate that 66 per cent. of the cases treated by skeletal traction had up to one-half inch of shortening; extensive shortening of two inches or more was present in only two cases.

FIG. 4-A FIG. 4-B

Fig. 4-A: Extensive comminution with loss of bone substance.

Fig. 4-B: Limb length was maintained by skeletal traction until soft-tissue wounds had healed, permitting internal fixation and replacement of bone by dual tibial onlay grafts with metal screws. Iliac ribbons of bone were placed in defect.

Anatomical alignment of fracture fragments should not be expected with skeletal traction; however, a satisfactory functional position can be obtained (Figs. 2-A and 2-B). In this series of cases, there was only one instance in which surgical intervention was necessary to correct malunion (Figs. 3-A, 3-B, and 3-C).

Delayed Primary Closure

Thirty-eight delayed primary closures were performed on the sixty-one compound fractures. In most instances this meant a débridement with closure of two wounds,—a wound of entrance and a wound of exit. In other cases, when the injury was caused by shell fragments, closure of as many as six wounds was necessary. No closure was considered successful until all wounds had healed. Twenty-two, or 58 per cent., of the thirty-eight delayed primary closures were successful. In the remaining cases with draining wounds, healing was by secondary intention, with no gauze or other foreign body inserted into the wound. These patients received penicillin parenterally, and their wounds were dressed only at very long intervals. In no instance was frank suppurative osteomyelitis encountered.

Open Reduction with Internal Fixation

Open reduction and internal fixation, in conjunction with skeletal traction, were considered necessary in eighteen of the sixty-eight cases. The reasons for the reparative surgery in these cases are as follows:

Delayed union	8
Loss of bone substance	6
Refracture	3
Malunion	1

TABLE III

FINAL LIMB LENGTH

Limb Length	Number of Cases
Full length to ½ inch of shortening	45
½ inch to 1 inch of shortening	12
1 to 2 inches of shortening	10
2½ inches of shortening	1
Total	68

TABLE IV

TYPES OF INTERNAL FIXATION

Tibial onlay graft with metal screws	4
Tibial onlay graft with metal plate and screws	3
Tibial onlay graft with screws and iliac bone	2
Iliac bone with metal plate and screws	9
Total	18

Where loss of bone substance was encountered, bone-grafting was carried out only when marked shortening would result or when sufficient bone contact was lacking to ensure union. Although seventeen patients suffered some loss of bone substance, open reduction and bone-grafting (Fig. 4-A and 4-B) were considered necessary in only six instances.

In the eight patients operated upon for delayed union, an average of three and one-half months had elapsed since the injury. This may be considered a little early to form an accurate opinion. The decision to operate was based upon clinical evidence of motion at the fracture site and lack of callus formation at roentgenographic examination.

The three refractures occurred at the end of five, five and one-half, and six months, respectively, which undoubtedly was too early to have solid bony union. One of these patients had a contributing injury when he was thrown to the floor of a bus while on his first pass from the hospital.

The one case of malunion occurred in a patient who, in addition to a transverse fracture, had sciatic-nerve paralysis, suffered from a causalgia requiring lumbar sympathectomy, and had repeated attacks of renal colic. Because of his complications, it was impossible to maintain proper immobilization in either skeletal traction or a plaster spica.

TABLE V

COMPLICATIONS

Complication	Number of Cases
Nephrolithiasis	3
Refracture of femur	3
Peroneal paralysis	1
Psychoneurosis	1
Fracture of tibial onlay graft	1
Bending of Lane plate with bowing at fracture site	1
Soft-tissue abscess (due to gauze dressing left in wound)	1
Refracture of wired patella	1
Frozen knee joint	1
Total	13

The types of internal fixation are shown in Table IV. Following open reduction and internal fixation, skeletal traction was resumed, to maintain position until bony union had occurred.

Complications

The complications encountered in this series of sixty-eight cases are considered minimal (Table V). All of the patients were comparatively young adults, in good general health at the time their injuries were sustained. Three patients had nephrolithiasis. One of these, as mentioned previously, also had causalgia. This patient had fractured his tibial onlay graft, while still in traction.

The patient with psychoneurosis was able to complete the treatment of his fracture on the orthopaedic ward.

Another patient returned from a week-end leave, complaining of pain at the fracture site with weight-bearing. Roentgenograms showed that the metal plate was bent and that there was bowing of the femur at the fracture site. When he was questioned, the patient admitted that he had walked without the aid of brace or crutches. This occurred six months after internal fixation of the fracture.

The third refracture occurred in the patient who sustained an additional injury in a fall in a bus.

In one patient, who had had an uneventful convalescence with union of his fractured femur, a very definite soft-tissue abscess developed when he became ambulatory. The patient had little complaint of pain, and there was no evidence of bone destruction by roentgenogram. At the time of incision and drainage of the abscess, a four by four gauze was removed, which had been left in his wound at the time of débridement or delayed primary closure.

Due to refracture, it was necessary to do a partial patellectomy on a patient who had had a wiring of a fractured patella overseas.

Another patient required a "quadriceps-plasty" for a frozen knee joint. This improved his flexion from a fixed position at 180 degrees to flexion at 135 degrees.

SUMMARY AND CONCLUSIONS

Skeletal traction is an efficient method of treating compound, extensively comminuted, oblique fractures of the femur.

In the presence of extensive wounds of soft tissue and bone, skeletal traction is definitely the treatment of choice.

Supracondylar traction is preferred to traction through the tibial crest, because there is less chance of infection or of pressure necrosis of soft parts or bone. Traction through the involved bone is more efficient than traction through the tibial crest.

OPEN REDUCTION AND INTERNAL FIXATION OF FRACTURES OF THE LONG BONES*

BY HARRISON L. McLAUGHLIN, M.D., SAWNIE R. GASTON, M.D., CHARLES S. NEER, M.D., AND FREDERICK S. CRAIG, M.D., NEW YORK, N. Y.

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This paper presents a report of cases treated on the Fracture Service of the Presbyterian Hospital in New York, under the direction of William Darrach and Clay Ray Murray, during the last twenty years. It deals specifically with the results in 200 consecutive shaft fractures of the weight-bearing bones, treated by open reduction and internal fixation.

No follow-up was considered adequate until the patient had been examined at appropriate intervals for a period of at least a year. Patients with fractured femora were followed for an average of 5.4 years, and those with fractured tibiae for 4.1 years. There were six deaths. Four were the result of concomitant injuries and occurred within the first few days. One resulted from kidney disease, eight weeks following fracture; and one patient died in the electric chair, seven weeks after injury. Fifteen cases had inadequate follow-up studies. The progress of the fracture was uncomplicated in these cases, when the patients were last seen. The remaining 179 cases, with adequate follow-up, form the basis of this report.

Evaluation of the results from open reduction and internal fixation leads to erroneous conclusions, unless the material analyzed is first classified according to the groups in which the method was used. In this study, the cases were separated into three groups (Table I):

TABLE I

OPEN REDUCTION AND INTERNAL FIXATION IN 200 CONSECUTIVE SHAFT FRACTURES

	Tibia	Femur
By choice	53	12
By necessity	10	47
Compound fractures	74	4
Totals	137	63

1. *Operation by Choice:* This group includes all cases in which the same eventual result might have been anticipated by the use of other methods of treatment.

2. *Operation by Necessity:* This group includes the cases not considered amenable to treatment by other methods, or those in which operative fixation was expected to produce results definitely better than could be obtained by other methods.

3. *Compound Fractures:* The various effects of an open wound upon fracture treatment warrant separate consideration of this group of cases.

The numerous common variants influencing success or failure of fracture treatment will not be discussed in detail in this report. An analysis of the role of such factors as the proper choice, timing, technique, and philosophy of operative fixation, the continuity and

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948.

TABLE II

OPEN REDUCTION AND INTERNAL FIXATION IN 179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

	Immobilization after Operation (*Per cent.*)	Physiological Function Maintained (*Per cent.*)	Protected Early Weight-Bearing* (*Per cent.*)
By choice	9.8	86.9	81.9
By necessity	16.6	83.3	75.9
Compound fractures	56.0	43.9	42.1

* The average period of protected weight-bearing in all fractured tibiae in which internal fixation was done by choice was 4.3 weeks.

rationale of after-care, and the cooperation of the patient will be reported elsewhere. These factors have proved highly important in determining the quality of the individual results. Faulty judgment in the choice of patient or fracture usually predicated an unsatisfactory result. Except for defective technique, the most important single therapeutic factor in the production of poor results was operation done late or after other methods of treatment had proved ineffective. The ease of reduction, the efficiency of fixation, and the prognosis varied directly in proportion to the speed with which the operation was carried out.

Internal fixation in only one plane was found to be inadequate, unless supplemented by external immobilization. Internal fixation in at least two planes proved to be essential for secure stabilization of all shaft fractures. In the cases in which this was accomplished (Table II), maintenance of joint motion and muscle action throughout healing, as well as protected early weight-bearing, was found to be both possible and safe.

Postoperative management depended upon certain features of the case in question. External immobilization by plaster splints or encasements was used in the presence of the following conditions:

1. Unreliability or disorientation of the patient.
2. Fractures of the femur (spica) or tibia (toe-to-groin plaster) in children. In no child was internal fixation done by choice.
3. Decalcified or diseased bone, having poor holding power for screws.
4. Imperfect fixation due to comminution or loss of bone.
5. Imperfect fixation due to faulty operative technique.
6. Infection (local rest of the part by splints until the infection was under control).
7. Severe soft-part damage (local rest by splints until soft-part reaction had subsided).

All externally immobilized extremities except when in a plaster spica (as in fractured femora in children) were also placed in balanced suspension for elevation, ease of nursing care, and maintenance of motion in the joints not immobilized. In the absence of the indications just listed, the extremity was placed in balanced suspension which allowed motion in all joints. In fractures of the femur, the limb remained in suspension until sufficient healing had taken place to make protected ambulation safe. In fractures of the tibia, suspension was removed and protected ambulation was commenced as soon as the operative wound had healed and the associated soft-part reaction had subsided. Many patients with fracture of the tibia were given a molded splint to wear while sleeping, after the suspension had been discontinued.

Protection for ambulation was provided in the case of tibial fractures by a removable leg brace fitted with an ankle hinge, and in femoral fractures by a toe-to-groin caliper brace fitted with a knee-joint lock. Occasionally a plaster-of-Paris walking boot was substituted for the leg brace in fracture of the tibia. This non-removable, immobilizing form

TABLE III

OPEN REDUCTION AND INTERNAL FIXATION IN 128 SHAFT FRACTURES OF THE TIBIA AND FEMUR*

	Non-Union	Loss of Fixation
Femur	0	1
Tibia		
Compound	6	0
Simple	1	0

* In each of the 128 cases, motion was maintained; early protected weight-bearing was carried out in 118.

of protection was found to be inferior to a brace, and was used only when justified by some factor of time or expense.

The external immobilization necessitated by inadequate internal fixation usually was found to offset the main benefits of the internal fixation. Table III gives ample proof that the absence of external immobilization did not jeopardize the security of adequate internal fixation. The single loss of fixation occurred two months after operation in a patient who refused to wear his brace. The record fails to show any specific reason for the one non-union in a simple fracture of the shaft of the tibia. The cases of non-union following compound fractures of the tibia were all accounted for by the circumstances of the local lesions.

An adequate technique of fixation has proved of tremendous importance. By comparison, the fixation materials used have proved unimportant. Although various metals have been used with success, stainless steel has been found most dependable for general use. Vanadium has been discarded as unsatisfactory. Many Vitallium plates have been fastened to bone with stainless-steel screws without any discernible untoward effect.

Electrolytic reactions have been observed commonly at operations for the removal of stainless-steel fixation. The amount of reaction has varied directly with the duration of the exposure, and has been unrelated to the amount of metal exposed to the action of the tissue fluids. Frequently the reaction has been centered around the tightest of the screws to be removed, while adjacent looser screws were uninvolved. Despite laboratory postulates to the contrary, neither loosening, loss of fixation, nor interference with union due to electrolysis has been observed.

In addition to compound fractures in which the material producing internal fixation was inserted as a temporary splint designed to be removed after bone healing, late removal of fixation material for relief of local pain or tenderness was required in twenty cases. Evidence of some electrolytic reaction was observed in most of these cases, and could reasonably be considered as contributing to the production of local symptoms. To date,

TABLE IV

BONE HEALING IN 179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

	Tibia			Femur		
	No. of Cases	Union	Non-Union	No. of Cases	Union	Non-Union
By choice	51	50	1*	10	10	
By necessity	10	10		44	43	1*
Compound fractures	60	54	6**	4	4	

* Successful union after bone-grafting.

** Three patients had successful union after bone-grafting; two had late elective amputation; and the remaining patient was transferred to another hospital and was not seen again.

TABLE V

ANATOMICAL RESULTS IN 179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

	No. of Cases	Length		Axis	
		Normal	Short*	Normal	Visible Angulation**
By choice	61	58	3	61	0
By necessity	54	47	7	50	4
Compound fractures	64	59	5	63	1

* The greatest amount of shortening was 3 centimeters.

** In twenty-seven cases slight angulation was visible by x-ray, undiscernible by clinical examination.

this complication has not been encountered during the period of usefulness of the plate or screws. In fourteen additional cases, removal of the fixation material was required for other reasons.

"Electrolytic osteitis" has not been encountered as a clinical entity. Areas of bone absorption adjacent to plates and screws have been observed to be the seat of electrolytic reaction. Most areas of absorption, with or without electrolytic changes, were traceable to infection or defective technique of fixation. Although an undesirable phenomenon, electrolysis has proved to be of minor clinical significance as long as the fixation material was reasonably inert and had been properly applied.

RESULTS

Of 200 fractures through the shaft of the tibia or femur treated by open reduction and internal fixation since 1928, 179 are sufficiently documented to be included in an end-result report.

Bone Healing

At operation, a major portion of the tissue debris and hemorrhage usually was evacuated, so that in cases with adequate fixation there was minimal formation of external callus. In the presence of non-rigid fixation, the amount of callus usually was increased. Bony union in rigidly fixed fractures occurred by gradual disappearance of the fracture line; consequently an estimate of the time of bony union was impossible. Clinical evidence of union in these cases was present from the start. The incidence of bony union and of non-union is recorded in Table IV.

Wound Healing

Fifty-nine simple fractures of the femoral shaft were operated upon. There were no

TABLE VI

ADJACENT JOINT MOTION IN
179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR*

	Tibia			Femur		
	No. of Cases	Normal	Limited	No. of Cases	Normal	Limited
By choice	51	50	1	10	6	4
By necessity	10	8	2	44	32	12
Compound fractures	60	51	9	4	3	1

* All motion defects of more than a few degrees resulted from some special complication or from external immobilization.

TABLE VII

SYMPTOMS ENCOUNTERED IN 179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

End Result	Tibia	Femur
Asymptomatic	87	44
Bad-weather pain	12	6
Other pain	5	1
Pain requiring late removal of fixation material	17*	7*

* Pain was relieved after removal of fixation material in all cases.

TABLE VIII

AVERAGE TIME OF ECONOMIC RECOVERY

	No. of Cases	Patients Capable of Former Work	Average Period before Ambulation	
			With Restricted Activities (*Months*)	With Full Normal Activities (*Months*)
Tibia (121 cases)				
By choice	51	50	1	4.5
By necessity	10	10	2.5	4.8
Compound fractures	60	57	2.4	7.7
Femur (58 cases)				
By choice	10	9	2	5
By necessity	44	43	3.7	6.4
Compound fractures	4	3	4	8

infections resulting in amputation. Three infections, two of which occurred after early fracture of the plate in cases with postoperative immobilization, resulted in local osteomyelitis, but did not prevent bony union of the fractures. Five trivial infections, involving only the skin or superficial tissues, occurred. The remainder of the operative incisions healed by first intention. Sixty-three simple fractures of the tibia were operated upon. Two infections, resulting in localized osteomyelitis but not preventing bony union, occurred. One trivial infection of the superficial tissues occurred. In the remaining cases, healing was uneventful.

Anatomical Results

Ability to maintain the length and axis of a fractured long bone, even in the presence of extensive comminution or actual loss of substance, is one of the important advantages of internal fixation. In all the cases herein reported, these two anatomical features were measured by both clinical and roentgenographic examination of the late results (Table V). Some of the twenty-seven slight angular deformities, visible only by roentgenogram, undoubtedly were contributed to by maintenance of motion throughout the period of healing and by protected weight-bearing prior to bony union. Many of them, however, resulted from faulty operative technique and were present in the roentgenogram immediately after operation. None of them caused trouble or were appreciated by the patient.

Range of Motion in Adjacent Joints

In all cases treated by open reduction and internal fixation as the method of choice, and in as many of the others as was possible and safe, maintenance of joint motion and muscle action throughout the healing period was the aim of the postoperative program. At times this objective was precluded by concomitant injuries, systemic complications, or defective fixation, requiring supplemental external immobilization. Table VI shows the end-result motion in the joints adjacent to the fracture. The patients having normal motion maintained an essentially full range from the start, and did not require a specific rehabilitation program to mobilize the involved joints following healing of the fracture.

Symptoms

As mentioned previously, localized pain or tenderness, requiring late removal of the means of internal fixation, developed in a certain number of cases. In some of these, nothing was found to account for the local symptoms. Electrolytic reaction between the fixation material and the tissues was present in others. Soft tissues, moving constantly over the surface of the fixation, occasionally resulted in the formation of an adventitious bursa which became painful. Subcutaneous fixation usually required eventual removal, because of local tenderness or pain. An analysis of the end-result symptoms is given in Table VII.

Time of Economic Rehabilitation and Disability

Of the 179 fractures reported, 113 had end results completely normal to both subjective and objective evaluation. If to these are added the twenty-seven cases rated less than perfect, because of a slight angular deformity, visible by x-ray but not discernible by clinical examination (Table V), 140 end results approximated normal. Information as to the patients' recovery of their former economic status is shown in Table VIII.

CONCLUSIONS

The use of open reduction and internal fixation, by choice, is vindicated in selected fractures of the shafts of the tibia and femur, and in certain compound fractures of these bones. In this study, good results were found to be much more dependent upon the way the materials for internal fixation were used than upon their composition. Fixation rigid enough to make possible a maintenance of physiological function throughout healing most nearly accomplished the primary aim of all fracture therapy,—to restore the patient to his usual activities as soon as possible and in a condition as nearly normal as possible.

DISCUSSION

DR. MATHER CLEVELAND, NEW YORK, N. Y. (Chairman): Three basic methods of treatment of fractures of the long bones have been presented, and each of these authors has borrowed at least one of the methods presented here today as an adjunct in his treatment of fractures of the long bones. This should indicate that no single method, which will yield satisfactory results in every instance, can be applied to all long-bone fractures. We endeavored to make these presentations as nearly comparable as possible by confining the discussion to weight-bearing long bones.

The fractured shaft of the femur is a grave surgical problem. Robert Kennedy presented a series of 120 consecutive fractures of the femoral shaft from Beekman Street Hospital. There was a mortality of 14 per cent., mostly within the first twenty-four hours. From the First Surgical Division of Bellevue Hospital in New York, there was an identical mortality of 14 per cent. Kennedy concluded that no single method of treatment is applicable in all instances.

Dr. Winant's sixty-eight patients with fractures of the femoral shaft are a selected group. The mortality is zero, because the deaths occurred overseas and the hardy or fortunate survivors reached the hospitals in the Zone of the Interior. Complications among these fit young men were minimal. Delayed primary closure converted many of the compound fractures into simple fractures. In no single instance among these compound fractures of the femur was there frank suppurative osteomyelitis. Some of the wounds healed by second intention, however. This represents an enormous advance over the situation which prevailed during the earlier campaigns, when patients returned from overseas with their wounds plugged with petrolatum gauze, bathed in purulent exudate. Penicillin also became readily available early in 1944, and this gave the Army surgeon

some needed assurance that delayed primary closure might be successful. It had been successfully accomplished twenty-five years earlier in World War I, without benefit of the antibiotics, and quite promptly forgotten.

When Dr. Winant speaks of patients requiring internal fixation, he is in reality dealing with those which presented problems in bone replacement.

The important contribution in this paper is the verification of our firm belief that delayed primary closure may be employed with success in a large proportion of these compound fractures, and that suppurative osteomyelitis fails to develop when intact skin is restored. I hope Dr. Winant may be able to carry out an additional follow-up study on his patients.

Dr. McLaughlin's paper is a very careful and interesting analysis of 200 fractures of the tibia, fibula, and femur, treated during a twenty-year period. Bony union by gradual disappearance of the fracture line, as described by the author, takes place in transcervical fractures of the femur. It is quite different if there is severe comminution or marked displacement.

There was an incidence of infection of a little under 5 per cent. in the simple femoral fractures operated upon, and of 5 per cent. in the simple fractures of the tibia. Happily, none of these had disastrous results, but there is a minimal risk despite the antibiotics.

These patients have been rigidly judged as to maintenance of length and motion in joints, and 73 per cent. were found completely asymptomatic under the best possible conditions. Patients recovered their former economic status in four and a half months after simple fractures of the tibia; with fractures of the femur, five to six months were required for simple fractures and eight months for compound fractures,—an excellent record.

Any series of open reductions of the femur is bound to represent a picked group, in that the immediate mortality has been screened out. In Dr. McLaughlin's series of sixty-three fractures of the femur, no mortality occurred.

I agree that technique is more important than metallurgy. Dr. McLaughlin stressed that proper selection of patients for open reduction is necessary to obtain optimum results in fractures of the weight-bearing bones.

MR. H. OSMOND CLARKE, LONDON, ENGLAND: I believe that the surgeon who treats fractures should have every facility at his command, from manual dexterity to all the complicated methods of screwing and grafting that you see today. I believe the safest method for treating fractures still is to reduce them with your two hands and hold the fragments in place with a plaster-of-Paris splint. In an analysis of 200 cases of fracture of the femur treated up to 1944 in Britain, the greatest difficulty we encountered was non-union, due to stretching and sometimes to infection. The infection did not occur from the original wound, because that was usually so adequately treated that it healed in a very short time. The sepsis we had to deal with was introduced by the surgeon. I believe you should treat these fractures conservatively if possible. If not you should operate, but only under the most ideal conditions of bone surgery. If those conditions are not available, it is far better to wrap the fracture in plaster-of-Paris or some other form of splinting and send the patient to a center for fracture treatment.

The best treatment is by conservative methods, with the fracture held by simple means until it has united, and immobilization of all the joints until union has occurred.

DR. H. EARLE CONWELL, BIRMINGHAM, ALABAMA: Dr. Winant has presented an excellent analysis of a properly supervised group of cases. The results show that skeletal traction is still the method of choice in most compound, severely traumatized fractures of the long bones, especially of the femur,—that is, in cases where the soft-structure damage is so severe that the bone and tissues could not withstand even the minimum trauma of an open internal fixation, or in those cases with such comminution that sufficiently large bone fragments are not present for the application of internal fixation. Dr. Winant failed to classify the soft-structure damage which is so frequently neglected in reports on fracture treatment.

Twenty-four years ago, I reported a series of 100 cases with fractures of the shaft of the femur, treated by skeletal traction; 50 per cent. were compound fractures, with an average soft-tissue damage of three plus. In this series only two had non-union which demanded open internal fixation, and these two were cases of compound fracture. In none of the compound fractures was there any severe infection. This was before the days of penicillin and the sulfonamides, but not before good surgical débridement was being practised. I have continued this treatment in such cases with results as good as, if not better than, those obtained by other methods. It is needless to mention that the surgical technique today should not be any less meticulous just because we have penicillin and sulfonamides, but often too much confidence is placed in these agents and surgical technique is neglected. I have always advocated the importance of good surgical débridement, and of mechanical cleansing and early closure of the wound.

For years I have treated all compound fractures of the femur by an overhead frame, with the lower extremity in the 90–90–90 position which was used in World War II. This position—that is, a right-angled flexion of the thigh at the hip and of the leg at the knee joint—makes compound wounds very accessible for dressing and inspection of the extremity.

For fractures through the upper two-thirds of the shaft of the femur, I prefer skeletal traction through the lower fourth of the femur; while for those in the lower third of the femoral shaft, I prefer skeletal traction through the upper fourth of the tibia.

Skeletal traction demands as good surgical technique in its application and convalescent observation as open reduction. It should not be applied or supervised by the inexperienced doctor; and, in most instances, it should be applied under general anaesthesia so that a real attempt at early closed reduction with muscle relaxation can be made.

The small Kirschner wire is far superior to the Steinmann pin for use in traction. Less trauma is done to the bone and surrounding tissues by using a Kirschner wire of average size.

Internal fixation in selected cases of fracture of the femur, as in any other fracture, should be done at an early stage when necessary, and the surgeon should be capable of selecting such a case early in its history. I am doing more internal fixations on simple transverse fractures of the femur with minimum soft-structure injury today than ever.

In order to present a fault of internal pin fixation (one example being the intramedullary pin advocated by Küntscher and others), I wish to say that the intramedullary peg was discarded years ago. I refer particularly to the beef-bone peg used by Hendon and the cow-horn peg used by Fowler and others. The objection to such intramedullary peg fixation was that it produced too much trauma to the vital bone-healing area at the fracture site, causing non-union in a large percentage of cases. Too often such treatment requires a more radical surgical approach than does simple internal fixation. A complicated fracture results, and more trauma is produced than by doing a simple open internal fixation. Let's not be misled by a fadist treatment, but deal with each case as an individual problem, and apply the treatment to the fracture and not the fracture to the treatment.

Osteomyelitis is an inevitable occurrence of the indiscriminate or indiscreet use of external pin fixation. I use such technique in a few selected cases.

Probably no other fracture clinic could make such an authentic report of results as Dr. McLaughlin and his associates have presented. I have observed for many years the rigid doctrine and practice of Dr. Clay Ray Murray and Dr. William Darrach in doing open reductions and internal fixation. Their set-up is ideal. We can never replace that personal factor in medicine, and we must ever be conscious of the fact that the Master makes the tools and not vice versa.

In the fresh fractures in our Clinic, we are averaging about 5 per cent. of open reductions with internal fixation. We feel that if an average of over 10 per cent. of open reductions occurs in a fracture clinic—that is, in fresh fractures—too many open reductions are being done and the practice of closed manipulation and reduction is being neglected. Our results by the closed method have been excellent; however, the case which demands open reduction and internal fixation should have early attention and proper mechanical fixation with the proper metal. By so doing, the best results will be obtained.

Dr. McLaughlin's report demands deep consideration before the technique presented is carried out. First, analyze yourself as follows: How good a surgeon are you? Do you know damaged tissue when you see it? Have you a proper set-up and well-trained assistants? Were you trained to do most of your work by the open or closed method? Last but not least, remember that a surgeon is not one who incises and thinks, but one who first thinks and reasons and in most instances does not incise. Dr. McLaughlin's presentation is for individual consumption and not for general distribution.

DR. R. I. HARRIS, TORONTO, ONTARIO, CANADA: Dr. Cleveland deserves our thanks in that he has planned this symposium around a discussion of the principles of treatment. We have listened to papers on the principle of open reduction and internal fixation, we have listened to a paper on the principle of traction, and we have listened to a paper on the benefits of external skeletal fixation *. Fractures, however, do not lend themselves to complete regimentation, as is the case in other fields of surgery, because they differ profoundly one from another, even in the same bone. What is successful in the management of one fracture may not be successful in the treatment of another, because of differences in the fractures themselves. Moreover, the application of methods of treatment of fractures will vary from place to place and from individual to individual. Many fractures demand for their best treatment more or less elaborate apparatus, the highest technical equipment from hospitals, the greatest skill in the use of that technical equipment, and experience and skill on the part of the surgeons; but fractures do not always occur in places or under circumstances where these things are available. Therefore, what is justifiable in the hands of a trained surgeon in one place in a properly equipped hospital is entirely unjustifiable elsewhere.

This is one of the difficulties in the discussion of fracture treatment, particularly in terms of undergraduate and postgraduate lectures on fracture treatment. Those who are concerned with undergraduate teaching frequently find themselves teaching one form of fracture treatment and practising something different. That is because they are skilled fracture surgeons and are justified in using methods which they would not be justi-

* By John R. Naden, M.D. Paper not received in time for publication in this issue.

(*Continued on page 114*)

CRITICAL OBSERVATIONS OF THE RESULTS IN THE OPERATIVE TREATMENT OF SCOLIOSIS *

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In the past thirty-one years, over 1,500 cases of scoliosis have been treated surgically at the New York Orthopaedic Hospital, including 850 cases treated since 1928 by the Risser hinge-jacket technique.

From a study of the data compiled in an analysis of these cases, we are now in a position to outline some of the causes of the substandard results, and to present the rationale of a somewhat modified type of treatment to correct these deficiencies, which is now coming into use by our staff.

In the study of many untreated cases of scoliosis, it has been observed that practically all of these patients attain an erect posture through adaptive bone growth, the head being centered perpendicularly over the sacrum, with the shoulders and pelvis level. It is true that a few, because of insufficient spinal segments, fail to attain this perfectly balanced state, but in all of them progress has been in that direction. This response of the spine to some developmental defect or muscle anomaly is, we believe, mediated through the constant action of the nerve tracts involved in the righting reflexes, and is accomplished through constant unilateral pressure on the growing bone in the spinal segments, according to the laws of bone growth. Thus we have come to feel that the development of a scoliosis is, in essence, a protective reaction on the part of the growing spine, endeavoring to maintain the erect posture in the presence of some unbalancing force or forces.

These statements are, indeed, self-evident when we realize that it is contrary to the laws of physics for a patient to stand erectly and to walk without the body mass being placed perpendicularly over the center of the weight-bearing platform. Since the pelvis is parallel to the walking surface, through the demands of equal limb length, it follows that all spines, scoliotic or straight, must be functionally perpendicular to the ground.

In a full-grown scoliotic spine, therefore, a so-called single primary curve is necessarily balanced by two reverse curves,—one above the primary curve and one below. If perfect balance has been attained (as is usual), the sum of the two reverse curves must be equal in degree to that of the primary curve. In the so-called double primary patterns, the two equal large curves balance each other, while the high cervicothoracic curve balances the lumbosacral return to the erect. To appreciate fully the significance of the total overall balance of the individual patient, it is necessary to analyze the spine and the individual as a whole, rather than limiting study to isolated spinal areas.

It must be constantly borne in mind that the individual vertebrae involved in scoliosis have adapted themselves and their facet articulations to a deviated position of the spine throughout their entire period of growth, and that the position they occupy is, for them, functionally normal. Consequently, the vertebrae involved have a range of lateral motion similar in degree to their counterparts in the normal spine, differing only in the fact that their motion is transposed to a deviated plane. These facts hold true for all the deviated segments in the scoliotic spine, both in the primary curves and in the curves in the reverse direction. It is a constant observation that the normal range of lateral vertebral motion is much more limited in the high thoracic region than in the lumbar area. For this reason, in the pattern of deformity of the single primary curve, we would expect the upper compensatory curve to be more resistant to spontaneous reversal after an induced correction below.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948.

This has been found to be true, in our series, and we now believe that this upper curve also requires inclusion in the correction and fusion procedure, and that it should be corrected by a similar degree.

With these considerations in mind, it is evident that, when correction of a single primary curve is effected, it is a mistake to carry the correction to a degree beyond the ability of the compensatory curves to reverse themselves spontaneously. When such an excessive correction is carried out, the balance toward which that patient has strived throughout the entire growth period will have been destroyed. Through the use of bend and tilt tests, we have found that, in the average fully matured spine, the upper and lower compensatory curves will reverse themselves to a total of approximately 20 degrees; and the greater amount of this reversal will have been attained in the lower compensatory area. Therefore, if balance is to be maintained postoperatively, it is evident that the so-called primary curve can be corrected in a mature spine by only about 20 degrees.

The importance of these factors is, we believe, brought out most clearly by a study of the postoperative findings in cases that have been overcorrected in a single area. If the fused area has been straightened to a degree beyond the ability of the compensatory curves to reverse themselves, and holds in its corrected position, the patient will be unbalanced; and to regain balance in order to walk erectly, he must lose correction in the fused area.

This unbalanced state induced by operation, which has remained static and uninfluenced by any active force while the patient has been recumbent in plaster fixation, is immediately subjected to a powerful active force, the righting reflex, which asserts itself the moment the change is made to the upright posture, and locomotion, with or without a plaster jacket, is begun. *A gradual but sustained loss of correction ensues;* occasionally, this undoubtedly occurs through a localized area of deficient fusion, but, as shown by repeated negative explorations, it occurs very often throughout the general immature fusion area, *without the presence of a pseudarthrosis.*

In cases in which the spine was fully grown, the amount of correction lost has been directly proportional to the amount of overcorrection, and the loss has not progressed beyond the point of balance. In fact, in most cases, the loss of correction proceeds to a degree which is just equal to the combined amount of reversibility in the compensatory curves, as shown by the preoperative bend and tilt tests.

In the event that excessive correction has been carried out in a spine that has not completely finished its growth, an even more interesting rebalancing sequel develops. If the fused segment holds in its overcorrected position, the patient is out of balance; and in the lumbar vertebrae below, which are still growing, a rapidly progressing curve develops in an effort to restore total body balance through bone growth. This progression of the lumbar curve after correction and fusion above is believed to be due solely to overcorrection in the upper fused area. The progress of the lumbar curve will be minimized, of course, if the overcorrection in the fused area is lost on the assumption of the position of weight-bearing.

We cannot emphasize too strongly the importance of studying *all* of the spinal curves and their spontaneous reversibilities before deciding to what degree to correct the so-called primary curve. Most of our difficulties have come from too much correction, rather than from too little. This is especially true in scoliotic spines in which growth is not complete.

From the foregoing discussion it is evident that, in the surgical treatment of scoliosis, if balance is to be maintained, the amount of correction advisable in a primary curve must be determined entirely by the precalculated spontaneous reversibility of the compensatory curves. Any correction to a degree greater than this should, we believe, be accompanied by simultaneous correction and fusion of all curves in the spine. Such correction must be adjusted to result in postoperative equality of the sum of the reverse curves to that of the primary curve, in each of their corrected positions.

In an effort to meet the challenge offered by these observations, we have now in use a type of jacket in which several areas can be corrected simultaneously.

It is obvious that any corrective modality, to be effective to the maximum, should vary somewhat with the pattern of the individual deformity, its location and flexibility. This is possible in this type of jacket, which we have called the "transection jacket". It was designed particularly to eliminate some of the deficiencies of the hinge jacket, and has aided greatly in improving and expediting therapy.

The transection jacket is a body jacket, including both the thighs and the head. It is divided transversely into two parts, the dividing line characteristically being at the junction point of two equal curves,—at or near the lumbosacral junction in the single primary lumbar curves, and at the lower end of primary thoracic curves. This jacket has neither hinges nor turnbuckles, and correction can be accomplished at any time within an hour after the jacket has been applied. In the flexible curves, the correction is usually effected by a manual shift of one transected portion of the jacket against the other. In the more rigid deformities, the hinge jacket is preferable; or surcingles or ratchets may be used to increase the force of the transection-jacket correction. In flexible single primary curves in the lower thoracic area, corrections have more recently been made by two transverse cuts in the jacket, leaving a central portion which embraces the central primary curve. This double transection has the particular advantage of forcing the three curves into alignment simultaneously. This makes it possible to take full advantage of all the correction obtainable in the primary curve and at the same time to correct the reverse curves. In such a manner, progress of lower curves in immature, incompletely grown spines is avoided; and a correction compatible with the balance for which every scoliotic strives through growth is always obtained.

This is in sharp contrast to the limited corrections permitted by the past method of single-curve correction, which has so often subjected the primary corrected area to the deleterious effects of fixed, incompletely reversible compensatory curves.

The cases treated by means of the transection jacket have failed to show loss of correction and have been well balanced, postoperatively. Although the areas of fusion have been somewhat longer than in the cases previously treated, the clinical results have proved the advantages of this method over those previously used. These cases will be reported in detail later.

It is apparent that, in the selection of the areas for fusion, as well as in the considerations of the amount of correction sought, we have deviated from the postulates of Ferguson. Our present criteria are:

1. In single primary curves, where correction has been carried out to a degree equal to the combined reversibilities of the compensatory curves only, fusion of the primary curve alone is indicated. This applies to those cases in which any type of correction has been employed.

2. In flexible single primary curves, where the double transection jacket has been used, simultaneously and proportionally correcting all curves in balance, fusion should extend to include all the originally deviated vertebrae in their corrected positions. This more inclusive area of fusion ensures the maintenance of a proportional amount of correction in all curves, and good postoperative body balance. This technique is being applied particularly to scoliotic spines in which a considerable amount of growth is still anticipated. Since no imbalance is produced and progressive deformity has been arrested, there is no reason to expect further progress.

3. In those so-called double primary curves, where the pattern is essentially that of two opposing large curves, we employ exclusively the single transection jacket and fuse the total extent of both curves, usually from the fourth thoracic to the fourth lumbar, in order to ensure that both curves, which have been corrected symmetrically beyond their normal lateral ranges of motion, will remain in that position.

CONCLUSIONS

From recent studies of postoperative end results in the treatment of scoliosis, we have found what we believe to be the causes for substandard clinical end results. We have revealed that excessive correction of single primary curves by the hinge-jacket technique has caused subsequent loss of balance. As a result of the excessive correction, these primary curves of the spine have been forced to spontaneously re-establish their own body balance. We have presented the several courses taken by these cases in their postoperative spontaneous return to balance, evidenced clinically in recurrent primary deviations, or in new deformities in adjacent areas of the spine.

In conclusion, many of the substandard results in the hinge-jacket treatment of scoliosis at the New York Orthopaedic Hospital have been traced to excessive correction in single primary curves. Further, the failure of compensatory curves to reverse spontaneously, in response to jacket correction of a single primary curve, is a consistent finding. Jacket corrections which do not take into consideration multiple spine deformity and total body balance are doomed to relative failure, either by compensatory phenomena, which develop secondarily, or by loss of primary correction.

Finally, more comprehensive principles of corrective therapy have done much to improve and to expedite surgical therapy. The transection jacket, after four years of use on more than 100 cases, has proved a highly valuable adjunct.

DISCUSSION

DR. ALBERT B. FERGUSON, BROOKLINE, MASSACHUSETTS: It has been a great pleasure to study the papers of Dr. von Lackum and Dr. Cobb. Both contribute toward the solving of some of the difficult problems of scoliosis. Both authors believe that the only effective treatment of scoliosis is correction and fusion, when it has become essential to stop progress and preserve alignment. In such a case, the question is: "What portion of the spine must be corrected and fused?"

In the given case, there are one or more curves which must be corrected and fused if satisfactory alignment is to be achieved and maintained; there may be one or more curves which will adjust themselves in a satisfactory manner without fusion. I see no point in arguing whether we should call a curve that requires fusion a major curve or a primary curve; neither term is wholly satisfactory. It would be helpful if we could agree on some term that all orthopaedic surgeons would understand.

The more important question is: "How can we identify these major or primary curves which must be included in a fusion?" The answer is not to be given in this short discussion. Some help will be gained by the study of what has been written about primary curves by such authors as Risser, Ullrich, Smith, and myself. Much help will be gained from the study of the present article by Cobb*. I will take the liberty of emphasizing only one point in this connection. I receive films of many cases which have had lateral bending to study passive correctibility, but very few which include a tilt test to study the power of the patient to correct the curve or curves in the lumbar and low thoracic areas. I venture to state that, even though one may be able to point out a rare exception, a curve which shows full correction on the tilt test will not cause damaging disalignment after fusion of other curve or curves. The test should be much more widely used, especially by those of lesser experience, as an aid in determining whether or not the lower half of the spine contains a curve or curves that do not need to be included in a contemplated fusion.

The tilt test is performed by roentgenographic examination in the erect position, with the pelvis raised three or four inches, first on one side and then on the other, by a sandbag under the buttock, if sitting, or a lift under the foot, if standing.

It is a fundamental principle of scoliosis that, after a deformity has been induced in one or more locations in the spine, the unaffected portions of the spine and the pelvis tend to align themselves in such a way that the body will be in balance, with the head erect over the center of the pelvis; this alignment will be attempted in the easiest possible way. This important principle has not been sufficiently appreciated, probably because it has been described by many cumbersome words. It is, therefore, a pleasure to hear Dr. von Lackum use the term "righting reflex" to express this principle briefly and pithily.

Dr. von Lackum has been making a serious attempt to avoid successive periods of correction and fusion for opposite curves, by means of a jacket designed for simultaneous correction of opposite curves with a single period of immobilization for fusion. The achievement of a commendable result by such means will obviously be of great value in the surgical treatment of scoliosis. He has used this jacket for only four years, so comparatively few cases have a three-year follow-up. Distressing experience warns me that this is not long enough for the evaluation of a method of surgical treatment of scoliosis. I trust that his enthusiasm for the method will

* Not yet received for publication.

continue to be justified, but I shall want to hear from him again in another three or four years before I advocate the use of this jacket. The type of correction obtained is like that of the Blount brace. More time is needed to determine whether or not the jacket is better than the brace.

Dr. von Lackum has emphasized overcorrection as a cause of substandard results. Why does he emphasize "overcorrection"? How have the results obtained with the transection jacket compared with those secured by use of the Risser jacket in patients having the proper degree of correction three years after fusion?

I do not agree with all of Dr. von Lackum's theoretical considerations. For example, I think asymmetrical bone growth is overemphasized, in relation to other factors which alter alignment of the spine; and a progressing, unfused, primary or major curve is described in some of his cases as asymmetrical growth resulting from overcorrection. I shall not discuss theory; improved results are the important thing, and both authors have done a great deal to achieve that end.

DR. ALBERT C. SCHMIDT, MILWAUKEE, WISCONSIN: Dr. von Lackum has pointed out that it is necessary to analyze the spine and the individual as a whole, rather than limiting the study to isolated spinal areas. Too often the study is limited to the lower two thirds of the spine, occasionally without standing films. To analyze a scoliosis properly, the various curves have to be studied in relation to a line parallel to the ground.

It is my understanding that a vertebra involved in a curve has a range of lateral motion not necessarily similar in degree to its counterpart in the normal spine, but proportional to the amount of structural changes in that vertebra. It has also been my observation that, although a spine which is solidly fused does lose some of its correction, it does not necessarily increase to the combined amount of reversibility of the compensatory curves.

Dr. von Lackum states that, when excessive correction has been carried out in a spine that has not completely finished its growth, the patient is out of balance; then, in the still-growing lumbar vertebrae below, there develops a rapidly progressive curve in a direction opposite to that of the fused area,—a natural effort to restore total balance. It would seem that the compensatory curve would have to decrease, instead of increase, or there would develop another curve in the opposite direction—namely, the same direction as the fused curve—in order to restore body balance.

I have had no experience with the transection jacket; however, it appears to be very effective in the double curves, and apparently requires a much shorter period in the hospital prior to surgery than many other methods. It also avoids undue pressure on the compensatory curves.

DR. HENRY F. ULLRICH, BALTIMORE, MARYLAND: Practically every essayist on scoliosis begins his paper with a statement to the effect that a study of scoliosis is very confusing. From there, he describes his concept of the deformity, leaving the reader or listener in agreement that confusion is the most constant finding. After hearing the excellent papers by Dr. von Lackum and Dr. Cobb, I wonder if it would not be possible to simplify our terms and standardize our terminology.

Certain phases of Dr. von Lackum's treatment of this deformity stand out in my mind:

First, scoliosis affects not only the entire spine, but also the entire individual. Let us keep our minds fixed on more than the so-called primary curve.

Second, the choice of patients for operation is important. It is now possible to predict what a curve will be from expected growth. Indications for operation are pain and the amount of deformity which will be present when growth has been completed.

Third, the deformity depends not only upon the curvature or curvatures themselves, but also upon the relationship of one curve to the other. Restoration of balance and trunk displacement are, therefore, even more important than curve correction *per se*.

Fourth, fusion-area selection cannot be emphasized too strongly, and we must keep in mind the simple fact that for every degree of correction there is a correct area which should be fused to restore balance. The less the correction, the longer the fusion area; and the greater the correction, the smaller the fusion area. By keeping in mind the fact that a so-called compensatory curve with structural changes can behave as a so-called primary curve, we realize that compensatory curves do not snap back to the erect the moment the tilt of the erect vertebrae of the primary curve has been removed.

In closing, I would like to emphasize the importance of balance, as compared to correction, in treatment of this deformity. The patient is more interested in balance from a cosmetic point of view than in the number of degrees of correction shown in a roentgenogram.

The transection jacket, I believe, is a valuable contribution which aims at restoring balance of the entire spine, instead of hoping for it later, as happened occasionally with use of the hinged jacket. I wonder if the extreme lateral bending at times did not aggravate the existing ridging in the vertebral bodies in compensatory curves, and in that way hinder the straightening of the unfused portion of the spine. This type of jacket tends to minimize this, and, I believe, is well worth the longer fusion area that is necessary.

DR. WALTER P. BLOUNT, MILWAUKEE, WISCONSIN: I ask the privilege of making two points with regard to the scoliosis brace. Dr. Schmidt and I developed this brace together. We prefer to call it the Milwaukee

(*Continued on page 140*)

RESTRICTED JAW MOTION DUE TO OSTEOCHONDROMA OF THE CORONOID PROCESS

BY RICHARD T. SHACKELFORD, M.D., AND WEBSTER H. BROWN, M.D., BALTIMORE, MARYLAND

From the Departments of Surgery and Radiology of the Johns Hopkins Hospital and University, Baltimore

In 1943, the authors [1] reported two cases of osteochondroma of the coronoid process of the mandible. They pointed out that the tumor had been an unrecognized cause of progressive limitation of motion of the jaw, and that its recognition by roentgenograms taken in the usual position employed for studies of the mandible was unlikely. Special positions, to be used for more accurate detection of this condition by roentgenography, were described. As far as could be determined at that time, no previous reports of this condition had appeared in the literature, nor have any been found subsequently. The fact that four such cases have been observed within our own limited practice makes us believe that this lesion, although uncommon, occurs more frequently than is recognized. It is the purpose of this paper to report a follow-up of the original two cases, to record two additional cases, and again to call attention to the condition and the means of its recognition and correction.

CASE 1. F. K., a fifteen-year-old boy, first came to the Johns Hopkins Hospital in June 1936, complaining that painless progressive swelling of the left side of the face had been present for three years. Except for the fact that forceps had been used at birth, there was no history of trauma. He was known to have congenital syphilis. Examination showed a hard swelling, 3 by 4 centimeters in size, in the left zygomatic region. There were no signs of inflammation. The overlying skin and the movements of the jaw were normal. The Wassermann test of the blood was positive, but that of the spinal fluid was negative. Roentgenograms taken in the usual anteroposterior and lateral positions were interpreted as showing a tumor of the soft tissue, producing distortion of the coronoid process of the mandible and of the zygoma. Syphilis was considered the most probable diagnosis and intensive antisyphilitic treatment was instituted, but the swelling continued to increase in size. Limitation of the motions of the jaw was first noted in 1940, and increased progressively. At the time of readmission to the Hospital on January 15, 1942, the swelling of the left side of the face measured 6 by 4 centimeters and was bony hard. The mouth could be opened only a half inch and occlusion was imperfect. The Wassermann test was again positive. Roentgenograms taken in the usual anteroposterior and lateral positions did not define the lesion accurately, but the special positions employed by one of the authors (W.H.B.) showed a large osteochondroma (Fig. 1-B), arising from the left coronoid process and extending upward, outward, and forward, impinging on and distorting the zygoma. The bony tumor was removed (by R.T.S.); the resected zygoma was replaced by means of wire sutures; and the jaw recovered its normal motion. Convalescence was uneventful, and the patient left the Hospital on the eighth postoperative day.

In June 1947, five and one-half years later, the patient returned for examination. At this time he had no complaints; the jaw had a full range of motion and function (Fig. 1-C); and asymmetry of the face was perceptible only after close inspection. The operative scar was minimal.

CASE 2. H.P.O., a male, aged nineteen years, was admitted to the Johns Hopkins Hospital on March 29, 1942, on the service of Dr. George E. Bennett, complaining that limitation of motion of the jaw had been present for two years. The disability had previously been attributed to impacted wisdom teeth; these had been extracted in another city, followed by a subsequent severe local infection, but without improvement. Wedges between the teeth had later been used without benefit, and the patient was referred to Dr. Bennett for possible temporomandibular arthroplasty. At the time of admission, prominence of the right zygoma was noted, but nothing suggestive of a tumor could be felt. There was no evidence of inflammation. The mouth could be opened only 1 centimeter, but occlusion was good. The remaining physical findings and the laboratory studies, including a Wassermann test, were normal. Roentgenograms taken in the usual anteroposterior and lateral positions were not definitive (Fig. 2-A), but those taken in the appropriate position showed an osteochondroma of the coronoid process (Fig. 2-B) with erosion of the zygoma and of the superior maxillary bone. At operation (by R.T.S.) the zygoma was resected in segments, the tumor was excised, and the fragments of zygoma were replaced by threading them on a wire like a string of beads.

The postoperative course was smooth. The patient left the Hospital on the eighth postoperative day with a full range of motion of the jaw, but with inability to wrinkle the right side of the forehead. This

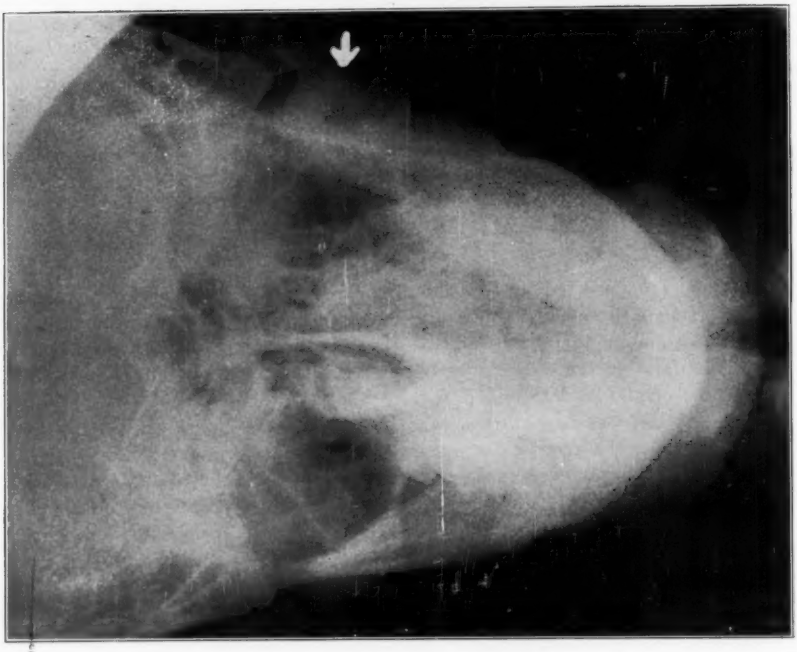

FIG. 1-B

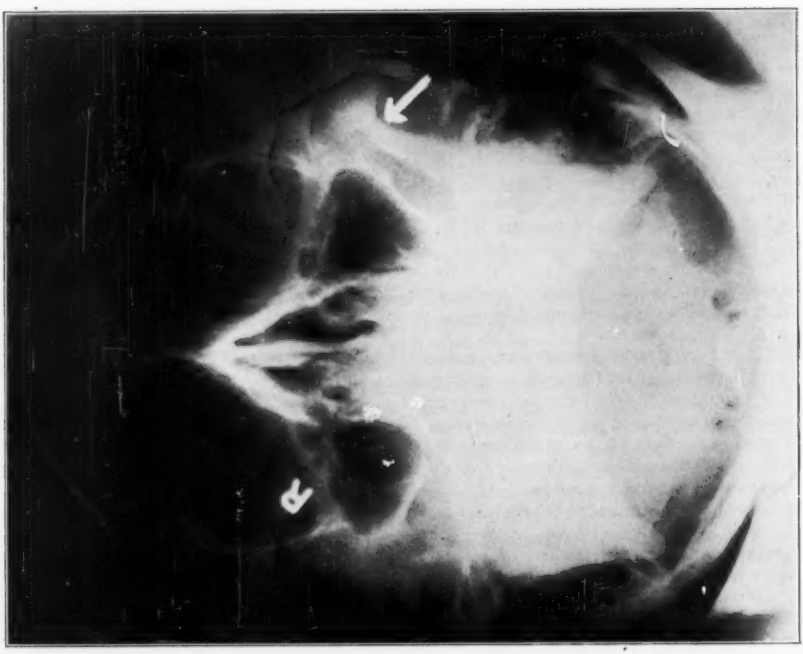

FIG. 1-A

Fig. 1-A: F. K. Case 1. Preoperative roentgenogram, taken in the sinus position with the arrow showing the tumor. (Reproduced, by permission, from *Surgery, Gynecology, and Obstetrics.*)

Fig. 1-B: Preoperative roentgenogram, taken in the special position, shows the tumor of the coronoid. (Arrow points to the tumor.)

Fig. 1-C: Photograph, taken five years later, shows full range of motion of the jaw as well as only slightly perceptible asymmetry of the face.

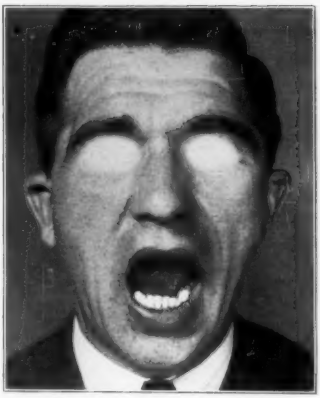

FIG. 1-C

condition persisted for several months, but then returned to normal. Within a year after his operation he was accepted in the Marine Corps, and served as an officer until the end of the War.

In May 1947, the patient returned for examination; at that time the range of motion and function of the jaw were normal; there was no perceptible asymmetry of the face; and the operative scar was minimal.

CASE 3. S. K., a man, thirty-eight years old, was referred to Dr. George E. Bennett on March 6, 1945, because of a cracking sensation in the right jaw when he opened and closed his mouth. This had been present for five years. In addition, the patient had noted that for the preceding two years the right side of his face had become increasingly swollen and motion of the jaw was becoming progressively limited. He had consulted many physicians during this time, without a diagnosis having been established.

When admitted to the Johns Hopkins Hospital on March 7, 1945, the right cheek was swollen and bony hard. Ability to open the jaw was noticeably limited and, when attempted, crepitation was palpable in the region of the right temperomandibular joint. The Wassermann reaction was negative. Roentgenograms (Fig. 3), taken in an oblique position, showed osteochondroma of the coronoid process of the right mandible.

On March 8, 1945, Dr. Bennett removed the tumor by the operative method to be described here (Fig. 5), but did not replace the resected section of the zygoma. Convalescence was uneventful and the patient left the Hospital on the seventh postoperative day. At that time motion of the jaw had returned to normal, and the crepitant noise had disappeared. He was examined on January 1, 1948, at which time the motion and function of the jaw were normal, the operative scar was minimal, and he had no complaints.

CASE 4. G. D., a white male, fifty-one years old, was admitted to the Veterans Administration Hospital at Fort Howard, Maryland, on February 28, 1945, for an unrelated condition. A routine history disclosed that in August 1943, two years before, he had been struck in the left side of the face and jaw by a passing truck. Since that time he had had a cracking noise in his jaw when he opened and closed his mouth, and had also noted increasing limitation of motion in carrying out this function. Examination showed fullness of the left zygomatic region as compared to the right, and he was unable to open the left side of the jaw as widely as the right.

Roentgenographic examination (Fig. 4) (by Dr. John T. Bracken, Jr.) in the anteroposterior sinus position showed fragmented hyperostosis in the region of the coronoid process of the left mandible, with an exostosis of the coronoid impinging on the medial surface of the zygomatic arch. There was some irregularity of the posterior surface of the zygoma, suggesting an old fracture. The Wassermann test was negative.

On May 18, 1945, an incision was made at a right angle to the left zygoma, one inch anterior to the left auditory meatus, and carried down to the zygoma. A three-quarter-inch section of zygoma was removed; and a bony tumor, which was fused with the zygoma on its posterior surface and which impinged on the coronoid process, was excised. After excision, the coronoid process moved freely when the jaw was opened and closed. No attempt was made to replace the resected segment of zygoma, and the wound was closed in layers. Convalescence was uneventful; the patient was well when last seen, at the time of his discharge from the Hospital.

The last case differed from the others in that the tumor was osseous rather than an osteochondroma; it arose from the zygoma instead of the coronoid; and followed a definite history of trauma with roentgenographic evidence of previous fracture of the zygoma. However, it is included because, due to its impingement on the coronoid process, it caused the same symptoms of progressive limitation of motion of the jaw.

The first three specimens were reported by the pathologist as being typical of osteochondroma, with stalks of bone capped by a mushroom-like head of cartilage. They were located at the site of attachment of the tendon supplying traction at that point,—namely,

FIG. 2-A

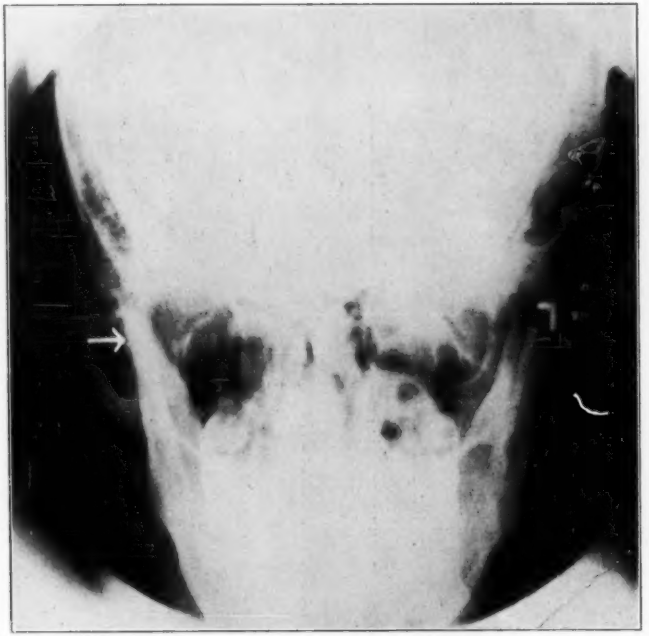

FIG. 2-B

Fig. 2-A: H. P. O. Case 2. Preoperative roentgenogram taken in the sinus position, with arrow pointing to the tumor.

Fig. 2-B: Preoperative roentgenogram of the jaw, taken in the special position, reveals the tumor. (Reproduced, by permission, from *Surgery, Gynecology, and Obstetrics.*)

FIG. 4

G. D. Case 4. Preoperative roentgenogram, taken in the anteroposterior position, with the arrow pointing to the tumor.

FIG. 3

S. K. Case 3. Preoperative roentgenogram, taken in the lateral oblique position, with the arrow pointing to the tumor. (This roentgenogram has been reversed.)

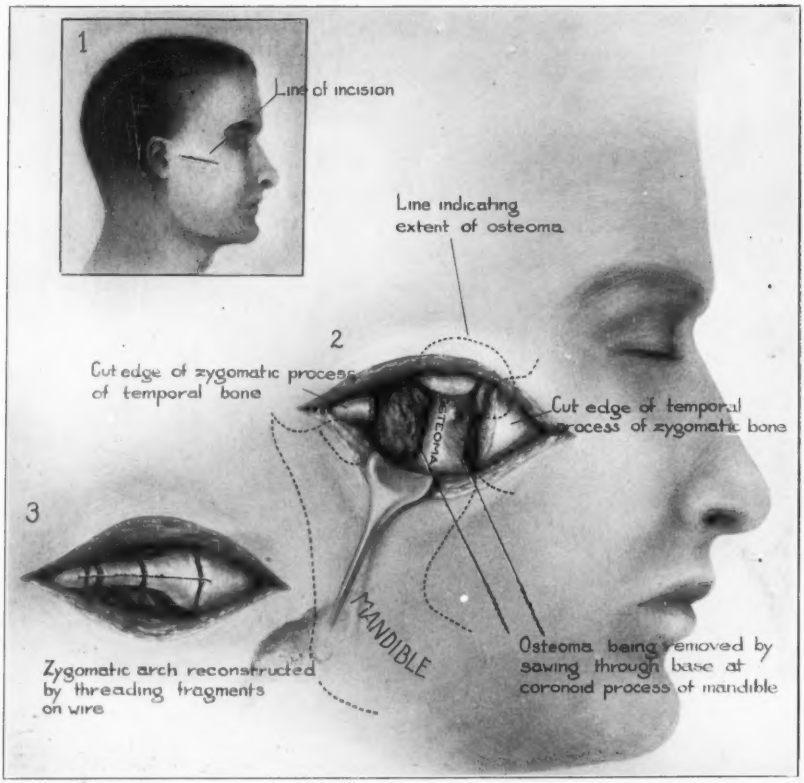
1
Line of incision
Line indicating extent of osteoma
2
Cut edge of zygomatic process of temporal bone
OSTEOMA
Cut edge of temporal process of zygomatic bone
3
MANDIBLE
Zygomatic arch reconstructed by threading fragments on wire
Osteoma being removed by sawing through base at coronoid process of mandible

FIG. 5

Steps in surgical removal of osteochondroma of coronoid process. (Reproduced, by permission, from *Surgery, Gynecology, and Obstetrics.*)

the tendinous insertion of the temporal muscle. In these three cases there was no history of previous trauma, and the explanation offered is the same as that for osteochondroma in other parts of the body, where it commonly occurs at the sites of tendinous insertions. Such characteristic locations are believed to be due to a defect in the periosteum at these points, permitting precartilaginous blastomata to escape or be pulled from the limiting membrane, and in time these cells produce an osteochondroma.

The diagnosis of osteochondroma of the coronoid process has not been easy. It was established in each of the first three cases only after several years had elapsed. The important points to emphasize in the diagnosis of this condition are a slowly progressive, painless limitation of movement of the jaw; unilateral malocclusion of the teeth; a bony-hard swelling in the region of the zygoma on the affected side; and a bony projection visualized by the roentgenograms, taken in the special position to be described. These positions are necessary to rule out such a lesion, as it is often not discernible in the anteroposterior and lateral positions routinely used in obtaining roentgenograms of the jaws.

The position in which this lesion is best shown by roentgenography is illustrated in Figures 6-A and 6-B. The important point is that the central ray is directed tangentially to the cheek of the affected side, instead of being centered on the mid-line symphysis of the chin. The anteroposterior position usually employed for demonstrating the nasal sinuses may also give a good view of this lesion.

Treatment consists of surgical excision of the growth. The operative procedure used (Fig. 5) is explained in detail in the authors' original article. In the first case, the resected zygoma was replaced by wiring it into place as a free graft; in the second, the zygoma had been removed in fragments and these were strung like beads on a wire across the bony defect; in the third and fourth cases, no attempt was made to replace that portion of the zygoma which had been removed. The cosmetic result was equally good in all four cases.

Injury to the facial nerve can be avoided by making the skin incision superior and parallel to the easily palpable inferior edge of the zygoma, below and parallel to which the zygomatic branch of the facial nerve courses. The incision is deepened until the zygomatic periosteum is incised at its *anterior* flange, where it begins to widen before articulating with the malar bone. The zygoma is bared subperiosteally until the amount desired for resection has been exposed. When this procedure is carried out subperiosteally, the zygomatic branch of the facial nerve is displaced out of danger inferiorly; and, if the stripping begins at the anterior portion of the zygoma and is not carried farther posterior than is necessary to resect the required segment, the temporal branch will likewise be spared as it ascends over the widened posterior squamous flange of the zygoma. This flange is posterior to the operative exposure required, and will be displaced posteriorly without harm if the operator carries the subperiosteal stripping farther toward the ear than is usually necessary. Temporary paralysis of either branch may occur if retractors are pulled too vigorously.

Ability to wrinkle the forehead was temporarily affected in two cases, but this function returned in each instance after a short lapse of time. There was no injury to the trigeminal nerve, Stensen's duct, or the oral mucous membrane. Each operation required two hours and was followed by an uneventful convalescence of seven days, during which the patient regained full range of motion of the jaw. These patients have been seen again

FIG. 6-A

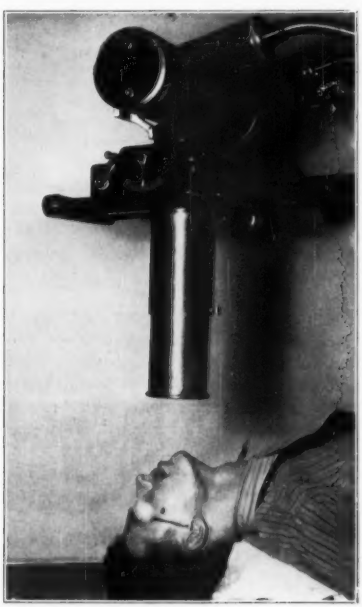

FIG. 6-B

Fig. 6-A: Showing the position to be used in taking a roentgenogram that is most likely to reveal the tumor. The central ray is tangential to the cheek, instead of being focused in the mid-line of the chin.
Fig. 6-B: The same position as used for Fig. 6-A, but with the photograph being taken from the side.

after intervals of from two to five years, and they have normal function of the jaw, symmetry of the face, and no sign of recurrence.

CONCLUSION

Progressive limitation of motion of the jaw can be caused by osteochondroma of the coronoid process of the mandible or by a bony growth in the zygoma. A special position for roentgenography may be necessary to demonstrate this lesion. The operative procedure described here has proved to be satisfactory.

1. Shackelford, R. T., and Brown, W. H.: Osteochondroma of the Coronoid Process of the Mandible. Surg., Gynec., and Obstet., **77**: 51–54, 1943.

DISCUSSION

Internal Fixation of Fractures of the Long Bones

(*Continued from page 101*)

fied in teaching to their undergraduate students. This is important, and I am happy to say that it has been emphasized before in this symposium. Many fractures will be treated by men who are only occasional fracture surgeons. That is obvious from the very nature of fractures and how they occur.

In a discussion of fractures and their treatment, we must bear in mind these modifying factors. Mr. Clarke summed the situation up well when he said that the simplest method by and large is the best. I could modify it a little by saying that the simplest method which will produce the best results, in regard to the type of fracture, the place in which it must be treated, the circumstances under which it must be treated, and the surgeon who will treat it, is the method which should be used. Closed methods are preferred. If open methods are necessary, then those should be used which close the wound after reduction, and other methods of internal fixation which leave no pins protruding.

There is no single method of treating fractures. They must be thought of as individual problems, according to the environment in which they will be treated and the persons who treat them.

Dr. Walter G. Stuck, San Antonio, Texas: As far as Dr. Winant's paper is concerned, I think he should have listed it as a description of "war" fractures. He is talking about severe injuries which were incurred overseas in patients who were transferred from hospital to hospital. His results were good with skeletal traction, but fair comparisons cannot be made between these cases and a similar series in civilian practice.

In the Presbyterian Hospital, with its superior staff and equipment, open reduction and internal fixation of fractures can be a successful common procedure, as Dr. McLaughlin has demonstrated. With the rest of us who are treating fractures in small private hospitals, it is essential that we continue our conservatism.

Dr. Edward M. Winant (closing): There is no doubt that where successful primary closure of wounds has been carried out, more definitive surgery can be undertaken, when necessary, in the treatment of these compound fractures. Dr. Conwell's use of the Thomas splint and Pearson extension apparatus apparently allowed freer knee motion than we were permitting. I believe that soft-tissue damage is important and should be evaluated, since it influences the end result. Whereas it was not recorded in this series of cases, it was taken into consideration in carrying out the treatment of these fractures.

One more precaution, which has been mentioned by Dr. Cleveland, is that great care should be taken in not depleting these compound, comminuted fractures of their bone fragments at the time of débridement and delayed primary closure.

Dr. Harrison L. McLaughlin (closing): Open reduction with internal fixation was not advanced in my paper as *the* method of choice. It was advanced as *a* method of choice in selected cases.

I would like to answer Dr. Conwell. According to stated statistics, I believe the incidence of open reduction on our Service is just about the same as on his. If on our Service in over twenty years we have operated on only 200 fractures of the shafts of the tibia and femur, of which only about sixty-one were done as a method of choice, it indicates that a patient has a reasonable chance of entering the Presbyterian Hospital in New York with a fracture of the leg and escaping without an open reduction.

CONGENITAL COXA VARA *

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Any decrease in the angle formed by the femoral neck with the femoral shaft is referred to as coxa vara[24]. Acquired coxa vara is a common deformity and may be due to a variety of causes. Congenital coxa vara is relatively infrequent and of unknown etiology. It occurs sufficiently often, however, to make its recognition as a distinct clinical entity most important. The authors propose, therefore, to summarize the current concepts of this deformity, to differentiate it from multiple congenital deformities, and to report fifteen cases.

Some confusion has arisen regarding congenital coxa vara, as evidenced by the following titles under which it has been described: "so-called congenital coxa vara" [8,44], "infantile coxa vara" [1,2,7,32,44], and "developmental coxa vara" [11]. These authors are all referring to a lesion best defined by Fairbank [14] as "a form of coxa vara occurring in children and associated with radiographic changes in the neck of the femur which are sufficiently characteristic to distinguish it from all the other types of this deformity". It is this lesion, characterized by a vertical fissure in the femoral neck [33], with which this paper is concerned.

REVIEW OF THE LITERATURE

In the year 1881, disabilities of the hip were still being considered as tuberculous or non-tuberculous, and congenital dislocation was one of the more popular non-tuberculous diagnoses. Fiorani, in that year, found fifteen cases in which previously a diagnosis of congenital dislocation had been made, and concluded that this rare form of limping was in effect due to a bending of the femoral neck. Little attention was attracted by his article, but Müller, in 1888, gave the first full anatomical description of coxa vara [12]; however, the condition he described was apparently an epiphyseal separation [42]. Hofmeister, in 1894, is generally given credit for coining the term "coxa vara" [41,42]. Finally, in 1896, Kredel gave the first detailed description of congenital coxa vara [3,26,44]. Zadek has given a careful review of the early articles describing this condition.

In 1899, Whitman made an impassioned plea for a more careful classification of coxa vara on the basis of etiology. As though in answer to this paper, Hoffa, in 1905, published his now famous monograph in which he reported two cases, undoubtedly congenital coxa vara, and included the first report of the microscopic pathological findings of the lesion in the femoral neck.

The period from 1905 to 1913 is characterized by a series of isolated case reports and two outstanding papers. Delitala reported one case and included a detailed account of the microscopic pathological findings. This was the second such report. Fairbank [14] states that Elmslie, in reporting on two gross specimens, was the first to recommend designating congenital coxa vara as "infantile coxa vara". Although this term has much to recommend it, it unfortunately has not been universally adopted.

* Abridgment of thesis submitted by Dr. Babb to the faculty of the Graduate School of the University of Minnesota, in partial fulfillment of the requirements for the degree of Master of Science in Orthopedic Surgery.

From 1913 to 1924, very little was written on this subject. Then, in 1924, Nilsonne reviewed the literature and reported five cases; he was the first to suggest an embryonic vascular disorder as the etiological factor in congenital coxa vara.

In 1926, Noble and Hauser, in a very comprehensive paper on coxa vara in general, gave an excellent description of congenital coxa vara. They attempted to solve the confusion on the subject by including all varieties of coxa vara present at birth under the term "congenital", and then dividing them into four types on the basis of additional aplasia of the femur and the presence or absence of other congenital deformities.

Fairbank, in 1927, had the misfortune to have a patient die on the operating table, of a massive pulmonary thrombosis. Subsequent examination of the hip disclosed that whereas the femoral neck was not visible on the roentgenogram, it was, in fact, intact but cartilaginous. In the following year, Fairbank contributed to the Robert Jones Birthday Volume a comprehensive article on infantile coxa vara, including a discussion of the roentgenographic recognition of the deformity.

In the years from 1927 through 1946, approximately seventy references to congenital coxa vara have appeared in the literature. Twenty of these are in English. Among the latter might be mentioned Barr's paper in 1929, in which he reported five cases; an excellent and comprehensive article by Zadek, in 1935; Ollerenshaw's presidential address to the Royal Society of Medicine, in 1938; a paper by Duncan, in 1938, in which he differentiated between congenital and developmental coxa vara and reported thirty-one cases; and Golding's paper, in 1939, in which he pointed out that the nine descriptions of microscopic pathological findings in the literature up to that date revealed nothing characteristic about this lesion. Of the foreign literature, Camitz in 1934, Pouzet [34,35], and Tavernier and Pouzet, in 1934, have contributed substantially; reference to them will be made later, under the discussions of etiology and treatment. Among the other articles written during this period were interesting case reports [1,10,13,19,27,28,41,43] and papers on coxa vara in general [36,38]. Very little has been written on this subject since 1939, which is analogous to the situation that occurred during and immediately after World War I.

ETIOLOGY

There is still no universal agreement as to the cause of congenital coxa vara. Kredel and Hoffa expressed a belief that intra-uterine pressure was responsible. Pouzet [35] and Duncan [11] held that the condition is the result of a developmental error. Such theories can neither be proved nor criticized [29]. It suffices to say that no hereditary factor has been demonstrated.

Then there are theories that have not withstood investigation. Rickets, which has never been shown to be coexistent with congenital coxa vara, can hardly be responsible. Trauma can be excluded, according to Hoffa, because of the unusual number of cases of bilateral lesions. Böhm suggested an atavistic theory, but Herz denied this because an examination showed that the angle of inclination of simians was not much less than that of man.

Walmsley, in a careful investigation of the upper femoral epiphysis, proposed the theory of a separately ossified diaphyseal spur. There is no doubt but that such a theory would account for the characteristic triangular fragment, to be described later; but how this theory would explain the more severe cases, in which the femoral neck is almost completely cartilaginous, is hard to understand.

Nilsonne, in 1924, presented what is perhaps the most attractive etiological theory,—that of an embryonic vascular disturbance. Camitz, in 1934, after examining microscopic sections, concluded that it was impossible histologically to distinguish between osteochondritis juvenilis (coxa plana) and so-called congenital coxa vara. Nilsonne's theory and Camitz' observations would seem to coincide in the postulation of a plausible explanation of the phenomena observed in this lesion. Since the femoral neck is not completely

ossified until the child is at least four years of age [12], even a postnatal vascular disturbance would explain the subsequent findings. Piergrossi, in 1939, in support of this hypothesis, demonstrated Bertolotti's metaphysitis as an evolutionary stage in congenital coxa vara. Duncan [10] supported this theory, and many of those who advocated the term "infantile" or "developmental" instead of "congenital" [1, 2, 39, 44] appeared to be in favor of it.

This modern tendency to explain congenital coxa vara as an aseptic necrosis [18] makes it all the more essential that the condition be separated from other obvious congenital deformities. An attempt will also be made to demonstrate pathologically that the coxa vara occurring as one of multiple congenital deformities is not the same as this infantile lesion, the cause of which may even be postnatal.

PATHOLOGICAL CHANGES

Noble and Hauser state that, at birth, the upper end of the femur is a mass of cartilage. There is a single, transverse, ascending edge of ossification which, during the fourth year, reaches the upper border of the neck. The neck, being completely ossified at the fourth year, separates the capital epiphysis appearing at twelve months from that for the greater trochanter, which begins to ossify only in the fourth year. Any disturbance of ossification of the neck, therefore, must occur in the first four years of life.

FIG. 1-A

Illustrative case of multiple congenital deformities of bones, including coxa vara. Coronal section through hip joint.

The earliest stages of congenital coxa vara are seldom seen. Ollerenshaw was shown by Herzog roentgenograms illustrating "small areas of rarefaction in the femoral neck" which apparently coalesced to produce the typical fissure, seldom evident before two years of age. By the fifth or sixth year of life, the femoral head has definitely slipped down, and the vertical fissure lateral to the epiphysis separates it from the remainder of the neck. What appears to be the head is in reality the anatomical head, the epiphyseal cartilage, and a triangular fragment of the neck, as will be demonstrated roentgenographically.

This descent of the head, then, due to a defect in the femoral neck, constitutes the gross pathological change, except for the more than occasional coexistence of a short femur. Shortening of the femur occurs at the upper end and appears to be a manifestation of an aplasia that is the result of some common underlying disturbance in ossification, as discussed in a preceding part of this paper. Such characteristics as a vertically displaced epiphyseal line and anteversion of the neck are roentgenographic features, not so evident in gross pathological specimens.

Descriptions of the microscopic pathological appearance of the defect in the femoral neck have been given by Hoffa, Elmslie, Delitala, Nilsonne, Camitz, Barr, Zadek, and Duncan [11]. There is nothing characteristic in the microscopic appearance of tissue removed from the femoral neck [3, 8, 11]. Barr reported finding the inclusion of embryonic cartilage in normal bone, and the occurrence of non-calcified osteoid tissue has been reported

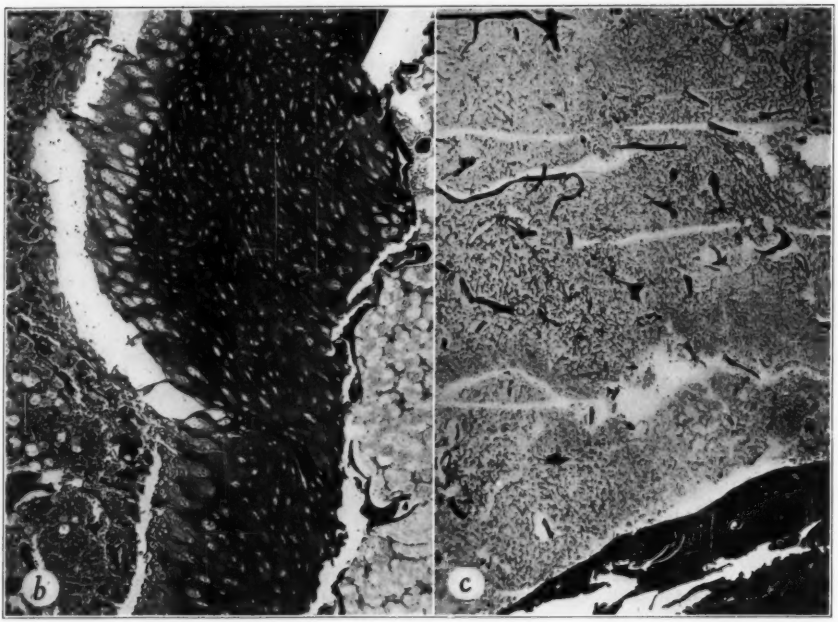

FIG. 1-B
Section through epiphysis (× 35).

FIG. 1-C
Section through mid-cervical region (× 6).

by Noble and Hauser. Otherwise, little can apparently be said about the microscopic pathology. Therefore, in an attempt to arrive at a fundamental pathological criterion for congenital coxa vara as herein defined, we can say that it is a lesion of the upper end of the femur with an incompletely ossified segment in the neck; it is composed of cartilage and osteoid tissue; and it sometimes includes gross aplasia of the upper femoral diaphysis.

The coexistence of multiple congenital deformities of other bones and coxa vara constitutes the differential problem. In an attempt to determine whether or not coxa vara in this relationship satisfies the pathological criterion laid down previously, such a case was investigated.

A white girl, aged eight years, was first seen at the Mayo Clinic in September 1928. Examination revealed multiple congenital deformities, including club-feet, flexion deformities of both knees and both hips, and bilateral coxa vara. Spina bifida occulta was also present. During a manipulation under anaesthesia in January 1929, the child suddenly experienced severe respiratory distress and died shortly afterward. At necropsy, death was found to have been due to fat embolism.

The resected specimens included one hip joint, consisting of part of the innominate bone and the head, neck, and upper part of the femoral shaft. This specimen had been sectioned in the coronal and horizontal planes through the middle of the head and neck. Accurate reconstruction was impossible, but moderate coxa vara appeared to be present, with a coxofemoral angle of about 110 degrees. No gross defect or triangular fragment was noted in the neck of the femur (Fig. 1-A).

Two blocks were cut, one to include epiphyseal cartilage and the other from the mid-cervical region, including the inferior cortex and extending almost across the width of the available neck. Both blocks were decalcified before they were sectioned, stained with hematoxylin and eosin, and mounted. Examination revealed a normal epiphysis with normal compact and cancellous bone in the cervical region (Figs. 1-B and 1-C).

It must be concluded, therefore, that since the condition did not satisfy the pathological criterion outlined previously, the case was not one of congenital coxa vara as herein defined. Such an observation, if made on other such specimens whenever they are available, may help to prove that there are two types of "congenital coxa vara" in infants,—

first, a true congenital lesion accompanied by multiple other deformities, and, second, a disturbance in ossification confined to the upper portion of one or both femora.

CLINICAL FINDINGS

Congenital coxa vara is usually discovered when the child starts to walk [24]. If no deformity, such as a short leg, had been previously noted, the parents then become alarmed at the appearance of a painless limp. Occasionally the limp is ignored and medical aid is not requested until adolescence. By this time the presenting complaint is a painful limp [42], with undue fatigue.

Physical examination typically reveals an otherwise normal child. The limp is easily demonstrated when the child walks, and resembles that of congenital dislocation of the hip. In fact, in cases of bilateral congenital coxa vara, the waddling gait and the marked lordosis are identical with those of congenital dislocation.

Examination of the hip reveals measured shortening, which is considerable in those patients with associated shortness of the femur. There is no spasm or tenderness, although abduction, internal rotation, and sometimes extension are mechanically limited [42]. The greater trochanter is elevated and prominent [3], and the Trendelenburg test is positive on the involved side [42]. The examining physician, suspecting a congenital dislocation, is then surprised to find that there is no telescoping of the femur and that the femoral head is still palpable beneath the pulsations of the femoral artery.

As mentioned previously, no other congenital deformities are present in a typical case.

ROENTGENOGRAPHIC EXAMINATION

Roentgenographic examination offers the most readily available means of studying this deformity. Unless one is familiar with the condition, the correct diagnosis is usually not made. The femoral neck is at once observed to be bent, so that the head is depressed and the distal part of the limb is thereby adducted [26]. The epiphyseal line for the head is more vertical than it is normally, and it appears to be branched like an inverted Y [42]. Brailsford states that this abnormal branch runs from the superior medial to the inferior lateral extremity of the neck, and isolates a triangular fragment in the inferior medial quadrant. It is not, however, a branching of the epiphyseal line, but a "disorganised segment", sometimes referred to as the vertical fissure, in which an abnormal ossification process has resulted in a defect not unlike that seen in aseptic necrosis [18] or localized osteochondritis [6].

The greater trochanter is elevated and may have a peculiar beaked appearance. The femoral head is comparatively large, somewhat translucent, and lies in the bottom of the acetabulum. The acetabulum may be deformed in outline, and shallow and defective inferiorly; shadows resembling those seen in osteochondritis have been noted [42].

At first glance, such a roentgenogram suggests a fracture of the femoral neck, but Zadek has stated that such fractures are extremely rare in children. When closer scrutiny discloses a short, imperfectly formed neck, with a zone of rarefaction which contains osseous nuclei and cuts off a triangular fragment [25, 43], one should have the necessary criteria for a correct diagnosis. When, as occasionally happens, the femur is short, owing apparently to an extensive failure of ossification at the upper end, the diagnosis is obvious. It is felt [14] that any such lesion with roentgenographic features so characteristic needs a more specific designation.

The untreated lesion that is seen during adolescence or later is much more deserving of the diagnosis, "ununited fracture". In effect, this is usually the state of affairs: What was originally a femoral defect has now become a complete dissolution of continuity. The trochanter may be riding much higher than at first, the deficient neck may have been completely absorbed, and true telescoping of the femur may now be present. The femoral head, strangely enough, is usually present and viable. Not only does this late lesion re-

TABLE I

DATA IN FIFTEEN CASES OF CONGENITAL COXA VARA

Case and Sex	Hip	Admission: Date	Admission: Age (*Years*)	Admission: Complaint	Treatment: Age (*Years*)	Treatment: Procedure	Follow-up: Time after Operation (*Years*)	Follow-up: Remarks
1 F.	R.	May 1938	3	Short leg since birth. Femur 4 inches short.	8	High osteotomy, internal fixation	3	No pain. No limp when shortening compensated. Extension 180 degrees, flexion 90 degrees, abduction 0 degrees. X-ray: ossification complete, coxa vara only partially corrected.
2 F.	R. L.	Jan. 1941	9	Painless limp. Onset at age of 16 months.	13 14	High wedge osteotomies, internal fixation	1½	No pain. Moderate limp. Extension: right 180 degrees, left 180 degrees; flexion: right 150 degrees, left 80 degrees; abduction: right 30 degrees, left 45 degrees. X-ray: ossification complete, coxa vara corrected. Left hip almost normal. Right hip movement limited by short neck.
3 F.	R.	Mar. 1936	6	Painless limp. Onset at age of 5 years.	16	Modified Brackett reconstruction	1½	No pain, limp, or gross shortening. Follow-up by questionnaire. No complaints regarding hip.
4 F.	R.	May 1943	15	Painless limp. Femur 4½ inches short. Misdiagnosed congenital dislocation at birth.	16	High wedge osteotomy, internal fixation	3	No recent examination. No reply to questionnaire.
5 F.	R.	Mar. 1943	2	Short leg since birth. Femur 3 inches short.	2½	Subtrochanteric osteotomy	3½	No pain. No limp when shortening compensated. Extension 180 degrees, flexion 60 degrees, abduction 50 degrees. X-ray: ossification complete, coxa vara corrected. Excellent result.
6 M.	L.	Oct. 1939	10	Painless limp. Onset at age of 2 years.	10	Subtrochanteric osteotomy	7	No pain. No limp. X-ray: ossification complete, coxa vara corrected. Complete range of motion. Trendelenburg negative. "Good as normal" hip. Excellent result.
7 M.	R.	Aug. 1939	14	Painless limp since 12 years of age, after minor injury.	15	Subtrochanteric osteotomy	6	No recent examination. No reply to questionnaire. Good result 3 years after operation. X-ray: ossification complete, coxa vara corrected.

TABLE I (*continued*)

8 M.	R.	Aug. 1937	13	No complaint regarding hip. Short tibia on opposite side.		No operation	Age 21	No pain. Slight limp. Negative Trendelenburg. Motions all normal except absent internal rotation. Doubtful whether true congenital coxa vara.
9 F. (Negro)	R. L.	May 1930	7	Painless limp. Onset at age of 2 years.	7	Subtrochanteric osteotomies	16	No recent examination. No reply to questionnaire. "Good result until 10 years after operation."
10 M.	R. L.	July 1928	9	Waddling gait. Onset at age of 2 years.		No operation		No follow-up data obtained. Child had multiple congenital deformities, history of birth injury, and foetal rickets at age of 2 years. Doubtful whether true congenital coxa vara.
11 M.	R.	June 1932	11	Painless limp. Onset at age of 3½ years.	22	Subtrochanteric osteotomy (Brackett reconstruction impossible)	4½	No recent examination. No reply to questionnaire. Union and unprotected weight-bearing 6 months after operation.
12 F.	L.	Mar. 1940	7½ months	Short leg since birth. Femur 1 inch short.	5	Subtrochanteric osteotomy	2	No pain. Slight limp. Shortening 1 inch. "She can run, skip, and roller-skate." X-ray: ossification complete and coxa vara corrected. Follow-up by questionnaire.
13 M.	R.	Dec. 1940	14	Painless limp. Onset at age of 13 years.	14	High osteotomy	6	No pain. Moderate limp. Shortening of ½ inch. Motion moderately limited. Follow-up by questionnaire. X-ray: coxa vara corrected.
14 F.	R. L.	Jan. 1941	10	Waddling gait. Inequality in limb length at age of 14 months.		No operation	Age 16	Pain and fatigue minimal with restricted activity. Motions limited 50 per cent. Hip reconstruction anticipated. Doubtful whether true congenital coxa vara.
15 M.	R.	Mar. 1947	9	Short limb since birth. Femur 7 inches short.	9	Modified Colonna reconstruction		At operation, no continuity of bone or cartilage could be demonstrated in neck region. A small femoral head was found, stuck to bottom of acetabulum.

semble an ununited fracture, but also, as will be shown later, it should probably be treated as such.

DIAGNOSIS

In a child, therefore, a diagnosis of congenital coxa vara should be considered for any painless limp resembling a congenital dislocation of the hip, if the femoral head is still palpable beneath the femoral vessels and telescoping of the femur is not present. If the roentgenograms suggest a fracture of the femoral neck, the criteria outlined should be considered before diagnosis of such a rare condition is made. No particular harm is done if the lesion in an adolescent person is mistaken for an ununited fracture, since that is in fact what is present, even though the etiological agent is non-traumatic.

TREATMENT

Congenital coxa vara was originally considered hopeless. If it is untreated, normal ossification rarely occurs, and the condition proceeds to an established non-union with the usual sequelae resultant upon a disruption of the hip joint, including arthritis, pain, and increasing disability.

A conservative attitude has been recommended by Barr and by Nilsonne. They have advocated non-weight-bearing with the limb in wide abduction and under traction, and Barr has suggested that a Brackett type of reconstruction be done after puberty. Nilsonne agreed that osteotomy is necessary for the more marked deformities.

The aim of treatment, as recommended by Pouzet [34], is twofold: first, to promote ossification of the cartilaginous neck, and, second, to correct the deformity. It is generally agreed that surgical intervention is necessary to accomplish both of these aims. Surgical procedures on the neck of the femur have proved universally unsuccessful [34, 35, 37]. In the child, subtrochanteric osteotomy has by far the greatest number of supporters [11, 14, 17, 23, 27, 29, 31, 33, 41, 43, 44]. In correcting the deformity, this procedure converts what was a vertical defect, across which played a sheering force, into a horizontal defect with a compression force. This has almost universally proved successful in promoting ossification. Although Zadek, in addition to the osteotomy, drills the neck, such a procedure does not appear to be necessary. Neither is a bone graft required [34]. The objection was raised by Noble and Hauser that subtrochanteric osteotomy offers only temporary benefit. This seems to be what Duncan had in mind when he urged extreme abduction of the distal part of the limb at the time of osteotomy. Peabody [31], in fact, suggested placing the limb in adduction before the osteotomy is done. He claimed that only in this way could the distal segment be brought into line with the proximal portion of the neck, an essential if maximal correction is to be maintained. With the advent of internal fixation, such as that secured by Blount with the blade-plate, such procedures as subtrochanteric osteotomy may be expected to yield even better results.

In the adolescent or adult group of patients, the problem is essentially that of treating an ununited fracture of the femoral neck. Of the reconstruction operations available, a Brackett type of repair is particularly in favor because of the high incidence of viable femoral heads found at operation. Should this type of repair prove impossible, selection of the alternative is obviously governed by the conditions encountered by the operating surgeon.

PROGNOSIS

If congenital coxa vara remains untreated, the head slips farther and farther down the shaft of the femur until it comes to lie on the floor of the acetabulum. To state it more correctly, the greater trochanter, atop the femoral shaft, goes higher and higher until abduction is impossible, owing to impingement of the trochanter against the ilium. The patient's gait becomes worse, and pain and fatigue add to the disability.

FIG. 2-A

Case 15. Roentgenogram of hip.

FIG. 2-B FIG. 2-C

Sections from distal edge of femoral head. No embryonal cartilage or osteoid tissue is visible. Inset shows gross appearance of femoral head.

It has been said that with efficient immobilization, healing occurs within about two years, just as in Legg-Perthes disease. Early investigators who tried to accomplish this result with complete rest and the limb in abduction and traction were disappointed.[14] Such treatment does not constitute adequate immobilization of the defect, either in coxa vara or in fracture of the femoral neck. Until the vertical defect has been corrected into a horizontal defect with a compression force across it, healing will not take place. Subtrochanteric osteotomy accomplishes this effect, and the enthusiasm for this form of treatment, plus the results in this series and others, bears out the claims made for it.

The prognosis in adolescents and adults is obviously not so good as in the child treated by subtrochanteric osteotomy at about six years of age. Some of the latter can even expect a hip functionally as good as on the normal side. In older persons, however, irreversible traumatic arthritis may already have been established. Reconstruction operations on adult hips are not likely to restore a hip to normal. Therefore, the prognosis in these hips will vary with the condition, the patient, and the surgeon.

THE CASES IN THE PRESENT STUDY

Of the fifteen cases reported here, all of the patients have been seen or treated since 1927, ten since 1937. Cases 1 to 10, inclusive, were treated at Gillette State Hospital; Cases 11 to 15, inclusive, were treated at the Mayo Clinic (Table I). The case numbers referred to are those given in Table I.

This series included seven males and eight females; one girl was a negro. The right hip alone was involved in nine cases, the left hip alone in two cases, and both hips in the other four cases. The average age at the time of admission was 8.8 years, although the majority of patients had had symptoms from infancy. Five of the patients were born with

FIG. 3-A

Case 1. Typical congenital coxa vara of right hip, at three years of age.

the involved extremity obviously short, and in each case the shortening was due primarily to hypoplasia of the upper end of the femur. Seven patients complained of a painless limp or waddling gait, with onset shortly after they had begun to walk. In the other three cases the limp did not develop until the ages of five years, twelve years, and thirteen years, respectively. The last two patients had only minor degrees of this deformity. The

FIG. 3-B
Appearance at age of eight years.

FIG. 3-C
Immediately after operation.

FIG. 3-D
Three years after operation.

FIG. 4-B
Immediately after operation on right hip, at age of thirteen years.

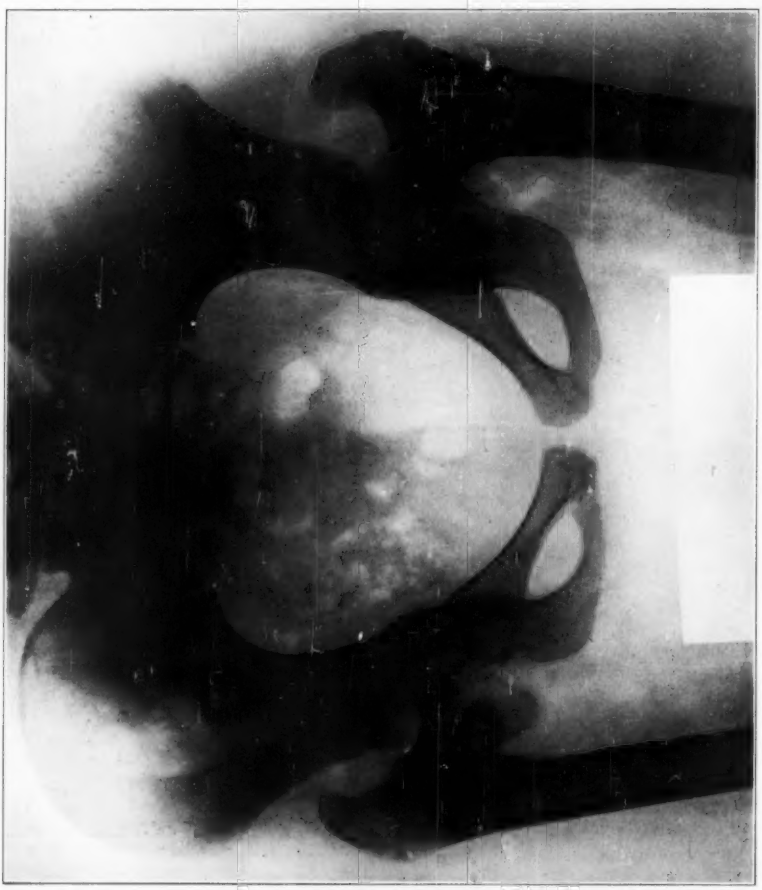

FIG. 4-A
Case 2. Bilateral congenital coxa vara, at age of thirteen years.

average age at operation was 11.5 years. The family histories, birth histories, and physical examinations were not remarkable, except that only two patients were smaller in stature

FIG. 4-C

Immediately after operation on left hip, at age of fourteen years.

FIG. 4-D

Eighteen months after last operation.

than normal (Cases 1 and 10). Apart from shortening of the femur, no congenital deformities were noted except in Cases 8, 10, 14, and 15, to which special reference will be made.

No surgical treatment was carried out in Cases 8, 10, and 14. In Case 8 the patient had a congenitally short tibia on the left, and the coxa vara of the right hip was an incidental finding. The roentgenogram in this case did not reveal a vertical fissure, and the flattening of the head was more characteristic of coxa plana than of congenital coxa vara.

FIG. 5-A

Case 11. Typical congenital coxa vara in a young adult, at age of twenty-two years.

FIG. 5-B

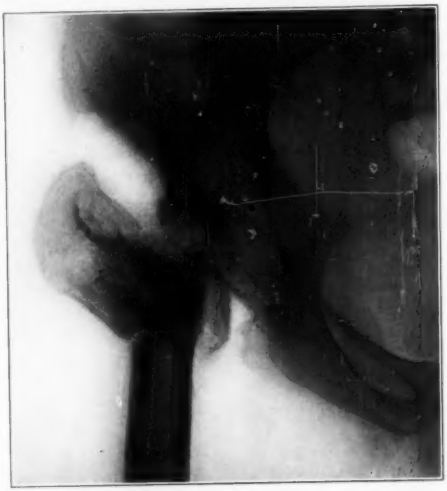

FIG. 5-C

Fig. 5-B: Immediately after subtrochanteric osteotomy (Brackett reconstruction was technically impossible).

Fig. 5-C: Three months after operation.

In Case 10 there were multiple congenital deformities and a history of birth injury and rickets. The roentgenograms in this case are not typical, and perhaps the case does not belong in this series. This case is illustrative, as is also Case 14, of the type of congenital hip deformity from which congenital coxa vara, as herein defined, should be distinguished. Case 15 is of particular interest and a detailed report follows.

CASE 15. A white boy, aged nine years, was first seen at the Mayo Clinic in March 1947. His complaint on admission was that a short right lower extremity had been present since birth. Birth and family histories were not remarkable. Examination revealed an otherwise normal nine-year-old boy, whose right lower extremity was seven inches (17.8 centimeters) shorter than the left, the shortening all being confined to the femur. The trochanter was prominent and higher on the right than on the left; the Trendelenburg test on the right was positive. Since the femoral head could not definitely be felt beneath the femoral vessels and telescoping of the femur was present, congenital dislocation of the hip was suspected. Roentgenograms revealed the faint outline of a femoral head still present in the acetabulum, but the femoral neck was not visible; gross aplasia of the upper portion of the femoral diaphysis was evident, with the epiphysis for the greater trochanter being present and riding high on the ilium (Fig. 2-A). The inferior ischial and pubic rami were ununited, and the upper end of the right fibula was absent.

Upon surgical exploration of the hip, a small, incompletely ossified head was found, stuck to the floor of the acetabulum. It was removed (Fig. 2-B, inset) and a modified Colonna reconstruction of the hip was performed.

No femoral neck, cartilaginous or osteoid, was demonstrated grossly. A block was cut from the distal edge of the head, decalcified, sectioned, stained with hematoxylin and eosin, and mounted. No embryonal cartilage or osteoid tissue, suggestive of a remnant of the neck, could be found.

In this case the lesion resembled clinically that of a congenital dislocation. Roentgenograms suggested a congenital coxa vara with a cartilaginous neck, as in Fairbank's case [13]. Surgical exploration, however, revealed that the femur had no neck, a fact which explains the telescoping observed on clinical examination. This should probably be classified as a coxa vara associated with multiple congenital deformities, including aplasia of the right innominate bone, right femur, and right fibula. Such a differentiation, of course, is of more than academic interest, as the treatment is obviously different.

In the eleven remaining cases (exclusive of Cases 8, 10, 14, and 15) the patients were operated upon; ten of the patients had osteotomy. In six cases (Cases 5, 6, 7, 9, 11, and 12) osteotomy was of the subtrochanteric variety and, except for a wire in Case 7, no internal fixation was required. Uniformly good results were obtained in these cases, correction of the deformity and the promotion of ossification being secured in every instance. It is felt that in the child of six to eight years of age this procedure is the one of choice, and that wide abduction of the limb after osteotomy is essential [11]. In the next higher age group, wide abduction is more difficult to obtain. Four such patients (Cases 1, 2, 4, and 13), whose average age was thirteen years, required high osteotomy, and internal fixation of the fragments was used to advantage.

One patient (Case 3) underwent a reconstruction operation. This patient was sixteen years of age at the time of operation and had what amounted to non-union of the femoral neck, with a viable and movable head. A Brackett type of reconstruction, followed by transplantation of the greater trochanter, proved successful.

The roentgenographic appearance in Cases 1, 2, and 11 is shown in Figures 3-A to 5-C, inclusive.

SUMMARY AND CONCLUSIONS

Congenital coxa vara is an infrequent deformity of the femoral neck in children, recognized since 1896 and characterized by a defect which pathologically and roentgenographically is not unlike that seen in aseptic necrosis. Except for its frequent association with a short femur, congenital coxa vara seems to occur entirely apart from other congenital deformities and to possess sufficiently distinguishing characteristics to warrant recognition of it as a separate entity.

The lesion is to be suspected in any child who is born with an obviously short leg or

who limps when walking is first attempted. The findings on physical examination suggest a congenital dislocation of the hip, with shortening, high position of the trochanter, and a positive Trendelenburg test. However, there is no telescoping and the femoral head is still palpable beneath the femoral vessels at the groin. The roentgenogram will confirm the diagnosis if the lesion is not mistaken for an ununited fracture of the femoral head, a rare condition in children.

The aim of treatment is to promote ossification in the neck of the femur and to correct any deformity already present. Subtrochanteric osteotomy with wide abduction of the distal part of the limb will correct the coxa vara, and conversion of the sheering strain across the defect into a compression force along the axis of the neck promotes complete ossification in a high proportion of cases.

Adolescent and adult patients with untreated lesions exhibit what amounts to nonunion of the femoral neck. Of the reconstructions available for such lesions, the Brackett operation is particularly suitable because of the high percentage of viable heads found at operation.

The series of fifteen cases reported here is fairly representative and purposely includes four examples of unusual coxa vara (Cases 8, 10, 14, and 15), from which it would seem advisable to differentiate the specific lesion defined in this paper.

It can be said, then, that congenital coxa vara as herein defined is *not* a proved congenital deformity. The frequent association of this lesion with a short femur is probably due to a common etiological factor, possibly avascular necrosis. Coxa vara associated with multiple congenital deformities is not the same lesion as that with which this paper is concerned. Subtrochanteric osteotomy at about six to eight years of age, with wide abduction of the distal part of the limb, is the treatment of choice.

REFERENCES

1. Armstrong, J. R.: A Case of Infantile Coxa Vara. With Notes on the Aetiology. Lancet, **1**: 1498–1500, 1935.
2. Bade, Arnt: Zur Abgrenzung der verschiedenen Formen von Coxa vara. Ztschr. f. Orthop. Chir., **59**: 53–75, 1933.
3. Barr, J. S.: Congenital Coxa Vara. Arch. Surg., **18**: 1909–1919, 1929.
4. Blount, W. P.: Blade-Plate Internal Fixation for High Femoral Osteotomies. J. Bone and Joint Surg., **25**: 319–339, Apr. 1943.
5. Böhm, Max: Infantile Deformities of the Knee and Hip. J. Bone and Joint Surg., **15**: 574–578, July 1933.
6. Brailsford, J. F.: The Radiology of Bones and Joints, Ed. 4, p. 257. Baltimore, Williams and Wilkins Co., 1948.
7. Burrows, H. J.: Incomplete Fracture of Femoral Neck in a Case of Infantile Coxa Vara. British Med. J., **1**: 569, 1940.
8. Camitz, H.: Étude comparée sur la coxa vara dite congénitale et l'ostéochondrite coxale juvénile (coxa plana). Acta Chir. Scandinavica, **73**: 521–575, 1934.
9. Delitala, Francesco: Sulla coxa vara congenita. Arch. di Ortop., **30**: 382–396, 1913.
10. Duncan, G. A.: Congenital Coxa Vara Occurring in Identical Twins. Am. J. Surg., **37**: 112–115, 1937.
11. Duncan, G. A.: Congenital and Developmental Coxa Vara. Surgery, **3**: 741–765, 1938.
12. Elmslie, R. C.: Injury and Deformity of the Epiphysis of the Head of the Femur: Coxa Vara. Lancet, **1**: 410–417, 1907.
13. Fairbank, H. A. T.: Unusual Case of Congenital Coxa Vara. Proc. Royal Soc. Med. (Section of Orthopaedics), **20** (Part 3): 7–8, 1927.
14. Fairbank, H. A. T.: Infantile or Cervical Coxa Vara. *In* The Robert Jones Birthday Volume. A Collection of Surgical Essays, pp. 225–241. New York, Oxford University Press, 1928.
15. Fiorani, G.: Quoted by Zadek and by Elmslie.
16. Golding, Campbell: Congenital Coxa Vara and the Short Femur. Proc. Royal Soc. Med. (Section of Orthopaedics), **32**: (Part 1): 641–646, 1939.
17. Guilleminet: Traitement chirurgical de la coxa-vara congénitale. Lyon Chir., **37**: 350–354, 1941.
18. Gütig, C., und Herzog, A.: Der Beginn der sogenannten "Coxa vara congenita". Aseptische Schenkelhalsnekrose. Beitr. z. Klin. Chir., **156**: 551–554, 1932.
19. Heep, R.: Beitrag zur Coxa vara congenita. Münchener Med. Wchnschr., **82**: 1728–1729, 1935.
20. Herz, Max: Der Affe und die Orthopädie. Ztschr. f. Orthop. Chir., **23**: 196–203, 1909.

21. Hoffa, A.: Die angeborene Coxa vara. Deutsche Med. Wchnschr., **31**: 1257–1260, 1905.
22. Kredel, L.: Coxa vara congenita. Centralbl. f. Chir., **23**: 969–973, 1896.
23. Lange, Max: Die Coxa vara, ihr klinisches Bild und ihre heutige Behandlung. (Eine klinische Vorlesung.) Münchener Med. Wchnschr., **85**: 1637–1641, 1938.
24. Mercer, Walter: Orthopaedic Surgery, Ed. 3. Baltimore, Williams and Wilkins Co., 1943.
25. Nilsonne, Harald: Beitrag zur Kenntnis der kongenitalen Form der Coxa vara. Acta Radiol., **3**: 383–406, 1924.
26. Noble, T. P., and Hauser, E. D.: Coxa Vara. Arch. Surg., **12**: 501–538, 1926.
27. Nové-Josserand, G.: Coxa vara traitée par l'ostéotomie sous-trochantérienne. Lyon Chir., **35**: 470–472, 1938.
28. Nové-Josserand et Pouzet: Forme spéciale de coxa-vara congénitale avec platyspondylie. Lyon Chir., **31**: 469–472, 1934.
29. Ollerenshaw, Robert: The Femoral Neck in Childhood. Proc. Royal Soc. Med. (Section of Orthopaedics), **32**: 113–118, 1938.
30. Peabody, C. W.: Bilateral Defect of Femoral Heads. J. Bone and Joint Surg., **9**: 288–293, Apr. 1927.
31. Peabody, C. W.: Subtrochanteric Osteotomy in Coxa Vara. Arch. Surg., **46**: 743–749, 1943.
32. Piergrossi, A.: Sulla metafisite femorale di Bertolotti (coxa vara infantile). Arch. di Radiol., **15**: 636–646, 1939.
33. Pouzet: L'évolution anatomique des aplasies du col fémoral (coxa vara congénitales, à fissure verticale). Lyon Chir., **31**: 712–724, 1934.
34. Pouzet, F.: Le traitement de la coxa vara congénitale. Presse Méd., **46**: 1095–1096, 1938.
35. Pouzet, F.: Sur le traitement de la coxa vara congénitale en évolution. Lyon Chir., **35**: 107–111, 1938.
36. Smith, N. R.: Coxa Vara. Practitioner, **124**: 432–443, 1930.
37. Tavernier, L., et Pouzet, F.: Traitement de la coxa vara à fissure verticale pendant la croissance. Lyon Chir., **32**: 65–73, 1934.
38. Taylor, V. J. M.: Coxa Vara. Med. Press, **207**: 238–241, 1942.
39. Teall, C. G.: Discussion on Deformities in the Region of the Hip-joint. Deformities at the Hip-joint in Children. Proc. Royal Soc. Med., **31**: 935–939, 1938.
40. Walmsley, Thomas: The Epiphysis of the Head of the Femur. J. Anat. and Physiol., **49**: 434–440, 1915.
41. Whitman, Royal: Further Observations on Coxa Vara, with Particular Reference to Its Aetiology and Treatment. New York Med. J., **69**: 73–81, 1899.
42. Zadek, Isadore: Congenital Coxa Vara. Arch. Surg., **30**: 62–102, 1935.
43. Zaremba, Juljusz: Congenital Coxa Vara. Report of a Case. J. Bone and Joint Surg., **17**: 450–452, Apr. 1935.
44. Zimmermann, Max: Untersuchungen über Krankheitsbild und Aetiologie der "sogenannten Coxa vara congenita" oder "Coxa vara infantum". Ztschr. f. Orthop. Chir., **68**: 389–415, 1938.

TUMORAL CALCINOSIS

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In 1934, when the first patient with tumoral calcinosis was examined by the authors, the unusual clinical and pathological process was recognized as worthy of follow-up study, and the accumulation of illustrative and clinical data was begun. From that time until the present, the authors have had under their care and observation three members of the same family of nine children, with tumoral calcinosis in various parts of their bodies. Pathological deductions have sometimes proved confusing and, since new tumors were developing from time to time in these children, the report has been delayed until the two living patients were adults. One has had no recurrence for twelve years, the other none for three years.

The term "tumoral calcinosis" has been used because of the similarity to the cases with this diagnosis reported by Alberto Inclan in June 1942. His conception of the pathology and the classification of the process coincides exactly with the findings in our cases. However, the familial features, metastatic characteristics, and autopsy findings in one of our cases add interesting data regarding this rather obscure and unusual pathological condition.

A review of the recent literature on the subject of calcinosis shows that there are two well-defined types which have been generally accepted. These were defined and described by Steinitz in 1931 as calcinosis circumscripta and calcinosis universalis. Pedersen, in 1943, gave a comprehensive bibliography of fifty-one articles on this subject, and reported that 137 cases of calcinosis circumscripta and 78 cases of calcinosis universalis had been collected from the literature.

The clinical, physical, and pathological findings of these conditions in no way fit the picture presented by Inclan. Ghormley, in his discussion of Inclan's paper, cites a family of three, one boy and two girls, who had lesions similar to those described by Inclan. Therefore, it would seem appropriate to add tumoral calcinosis as a third type. With the presentation of the authors' three cases of tumoral calcinosis, added to those of Inclan and Ghormley, a total of nine cases of tumoral calcinosis are contributed to the literature.

To differentiate these three types, each will be described briefly.

1. *Calcinosis circumscripta* usually occurs in middle-aged women at the period of the menopause. It is confined mainly to the upper limbs; small calcium deposits appear in the subcutaneous tissue of the fingers, frequently associated with Raynaud's disease, angiospastic syndrome, and scleroderma. The deposits or nodules are tender and the skin is atrophic.

2. *Calcinosis universalis* occurs in children and in older men. The deposits are widespread. They may be in the skin or in the subcutaneous, muscle, and fascial tissues; a whole muscle or a group of muscles may be involved. In children the prognosis is serious. Calcium may be deposited in the muscle interstices and connective tissue, or around nerves, fasciae, and sinews. The condition is chronic and progressive, causing local inconvenience. The patient may become more or less stiff and helpless. Some men having this condition show evidence of hypogonadism and high uric-acid retention.

3. *Tumoral calcinosis* occurs in young individuals of both sexes. There is probably a familial tendency. The tumors are large, rapidly growing to a definite, self-limited size; they usually occur in or near bursal sites, near large joints, and in connective tissue, immediately overlying bone and muscle attachments. The tumors are hard and lobulated, have fairly well-defined limitations in contour, are attached firmly to the underlying deep

structures, and may show some infiltration into the muscles. There is usually no pain, tenderness, or limitation of joint motion. There is a definite multilocular, cystic arrangement of the tumor, which has thick, rubbery walls, showing inflammatory foreign-body giant-cell reaction. Deep cystic areas are filled with calcareous material and some milky fluid. Surgical removal relieves the condition. Drainage and secondary infection, which occurred in one case, apparently aggravate metastatic calcification, and generalized amyloidosis may develop ultimately.

CASE REPORTS

CASE 1. D. D. (No. 34158) was first examined on April 27, 1934. He was a well-developed negro student, fifteen years of age, who complained of tumor-like enlargements on the posterior lateral aspects of both elbow joints. These tumors had first been noticed about two years before and had been gradually increasing in size. They were not painful, but were a noticeable deformity and he desired to have them removed.

The patient's previous health had always been good. He was one of nine children, and two brothers were similarly afflicted.

Physical examination disclosed equal-sized circumscribed tumors, about three and one-half inches (almost 9 centimeters) in diameter and two inches (5 centimeters) thick, located laterally and posteriorly, slightly above the elbow joint. On palpation, each appeared to be a semifluctuating mass, which was lobulated, slightly movable, and apparently attached to the deep soft-tissue structures. Manipulation did not cause pain, and there was no interference with elbow movement. Otherwise, the physical examination was negative.

The hemoglobin was 69 per cent., the white-blood-cell count 9,000. The urine was essentially normal. Attempted aspiration of the tumor produced nothing but blood.

On May 10, with a blood-pressure tourniquet applied to the upper arm, a posterolateral, curved longitudinal incision, seven inches (17.5 centimeters) long, was made over the right elbow region to the deep fascia. By blunt dissection, the integument was reflected from the encapsulated multi-

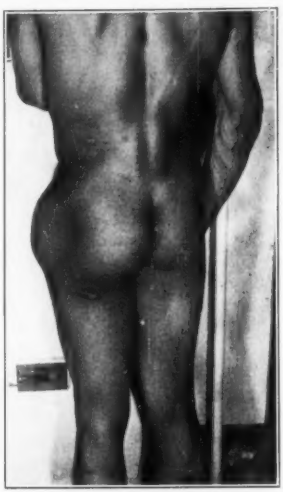

FIG. 1-A

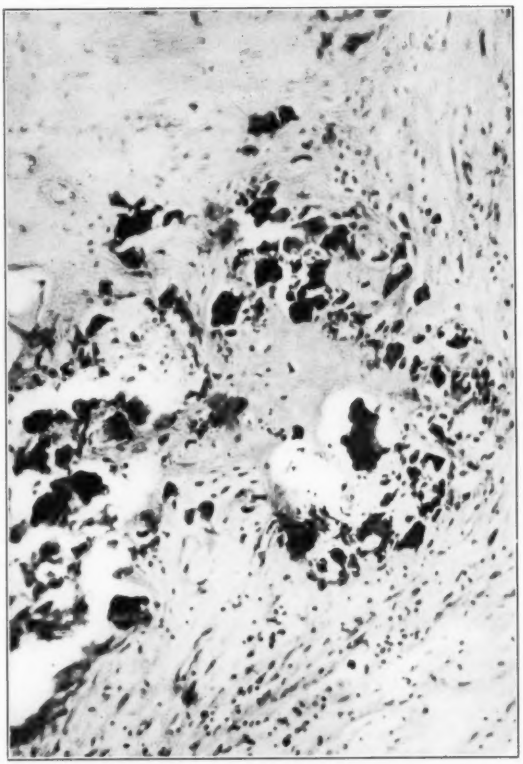

FIG. 1-B

Fig. 1-A: D. D. Tumor of left hip. There is no evidence of recurrence of tumors that were removed from elbows five years before.

Fig. 1-B: Photomicrograph (× 150) stained with hematoxylin-eosin. Tumor shows calcific deposits in fibrous stroma with a few inflammatory cells and foreign-body giant cells.

locular mass, which appeared to have its base on the lateral condyle of the humerus and to extend around posteriorly to the region of the olecranon. The mass was cut through, longitudinal to the base. The scalpel encountered a rubbery resistance and grating effect as it traversed the multilocular cystic wall. The cut surface showed a thick-walled, granulating membrane, which was pinkish-yellow with some markedly brownish-yellow areas. These cystic areas were filled with caseous or calcareous-appearing degenerating material, having a pasty consistency. The base was adherent to the ligamentous structures of the posterior and lateral portions of the upper margin of the joint. The capsules stripped easily from the surrounding tissues. The mass did not seem to invade the muscles or tendon structures, but rather pushed them aside in its development. The wound was closed after removal of the excess skin, and a pressure dressing was applied.

The left elbow was similarly approached and a similar mass was removed *in toto*.

Ice bags were applied to both elbows for the first forty-eight hours, and the patient had little discomfort. The wounds were dressed on the third day, and 30 cubic centimeters of blood was aspirated from the incision at the right elbow. On the fourth day the patient's temperature was normal and he was allowed to go home. On the ninth day the sutures were removed, and he left for a Civilian Conservation Corps camp in a distant location.

The specimen submitted for pathological examination measured about 5.5 centimeters in size, was slightly irregular in outline, and had a peculiar gross appearance. The stroma was whitish-pink, very firm, with small cavities containing a semimucoid granular and calcific material. The tumor was tough and, when cut, seemed gritty and offered increased resistance. Microscopically (when reviewed in July 1945 with all material reported later) there was a fibrous stroma in which amorphous and calcific debris was deposited. This debris was coarsely granular and the larger, definitely calcific masses seemed to be made up of clumps of this material. Around the calcific deposits were many multinucleated giant cells and inflammatory cells. Some of the cystic spaces which contained the calcific debris had synovial-like linings. The foreign-body reaction and inflammatory changes appeared to be a response to the calcific deposits. The diagnosis was calcinosis, involving periarticular soft tissues of the elbow. (The original report, given in 1934 by M. J. B., was probable ruptured sebaceous cyst with secondary inflammatory reaction.)

This patient was not seen again for nearly five years. On January 17, 1939, he came in with a large tumor over the greater trochanter of the left femur (Fig. 1-A). There had been no recurrence of the process in the elbow joints, as is evidenced by the photograph taken at the time. He had no pain in the hip, but objected to the disfigurement. On January 18, he was operated upon through a lateral longitudinal incision over the tumor mass. This mass was the size of a man's hand; it lay under the tensor fascia muscles and extended into the muscle substance of the glutaeus maximus. It was firmly adherent to the structures over the greater trochanter. The tumor resembled those of the elbows. The patient was in the Hospital for five days; in one week the stitches were removed, and about 50 cubic centimeters of bloody fluid was aspirated from the region. Healing continued and he returned to his position.

This specimen measured 15 by 8 by 5 centimeters. It was grossly nodular, fibrous, and cystic, with peculiar pasty, foreign, calcific deposits. The microscopic findings on review of the slide were similar to those described previously, and were typical of calcinosis (Fig. 1-B). (The original diagnosis on the basis of this material had been embryonic tumor, type unknown. M. J. B.)

Case 2. R. D. (No. 326230), brother of D. D., was first seen on June 16, 1936. He was a slight negro male, aged twenty-five years, who, because of his general condition, had never been able to do manual labor or work. He had been well and healthy until 1923, when a growth started on his right hip, which had gradually increased in size for about a year.

The patient stated that in 1924 an abscess of the right hip had been drained, and that there had been drainage off and on since then, without pain or limitation of motion. There was evidence of several incisions in the region of the hip over a large mass, which extended forward and backward, above the greater trochanter.

In 1932, a mass was noted in the right elbow. It had grown steadily, reaching its maximum size in about a year. It had not caused pain or limitation of motion. About six months later a similar tumor had begun to develop in the right axillary line, opposite the inferior angle of the scapula. It had grown steadily and had extended anteriorly and posteriorly from its original site, until it covered almost the entire scapula. A similar mass had started on the left shoulder, at the superior aspect of the joint; it had become quite large and protruding. Others occurred on the plantar surface of the foot, on the palmar surface of the wrist, and on the right lower ribs, at the anterior axillary line. All of these had grown for about a year and thereafter had not increased in size. None of them had been accompanied by pain, limitation of motion, or discharge.

The patient weighed 105 pounds and appeared markedly undernourished. His pulse was eighty-eight, blood pressure 118 systolic and 60 diastolic, respirations twenty-two per minute. On physical examination, dental caries were the only abnormal finding, except for the numerous tumors already described (Figs. 2-A and 2-B). A tumor approximately 7.5 centimeters in diameter was present on the superior border of the left shoulder joint. It was quite hard and immobile, and the skin was tight and stretched over it. The mass did not seem to be directly connected with bone. There was no limitation of motion, and no pain or discomfort.

FIG. 2-A

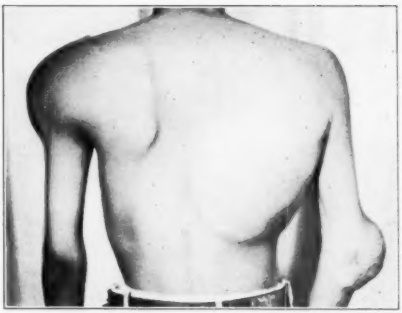

FIG. 2-B

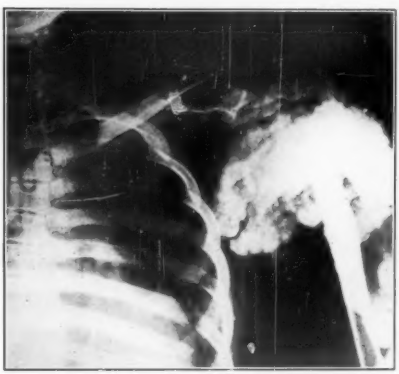

FIG. 2-C

Fig. 2-A: R. D. Multiple tumors in left deltoid region, left axilla, right lower chest, right elbow, and right hip (original site).
Fig. 2-B: Back view shows deltoid tumor on left, large scapular tumor and elbow tumor on right.
Fig. 2-C: Roentgenogram of left shoulder, showing extensive tumor mass in the deltoid region.

The mass in the right elbow was similar in consistency to that of the shoulder, although somewhat smaller. A similar mass, not very large, was seen on the lateral surface of the left hip, opposite the greater trochanter. The right hip had an open, discharging lesion from a very swollen and enlarged area over the greater trochanter. A small, circumscribed mass appeared on the palmar surface of the left wrist. There were several scars on the thenar eminence of the hand, where the patient stated a similar mass had been present, which had broken and discharged. On the left foot was a mass, 2.5 centimeters in size, on the proximal phalanx of the fourth toe, displacing the fifth toe. There were masses of moderate size in both axillae, and a mass, approximately 4.3 by 8 centimeters in size, on the lower right side, in the region of the lower ribs, extending toward the axilla.

At the time of admission to the Hospital, the patient's temperature was 100. The Wassermann reaction was negative.

Red blood cells	3,750,000
Hemoglobin	42 per cent.
White blood cells	9,600
Polymorphonuclear neutrophils	76 per cent.
Bands	1
Lymphocytes	21
Mononuclears	2

On June 23, 1936, anteroposterior stereoroentgenograms of the chest showed that the costophrenic angles, the domes of the diaphragm, and both lung fields were clear. The heart and great vessels were negative. In the soft tissues around the chest wall were numerous rounded areas of increased density. Anteroposterior roentgenograms of the left shoulder (Fig. 2-C) and lower portion of the humerus showed extensive, well-demarcated accumulations of structureless material of increased density. There was no evidence of bone involvement. The general appearance was that of an opaque material and loculated cavities.

Because of the large number of tumors and previous experience with the patient's brother, one of the authors excised the tumor of the right elbow on June 20, 1936, for further examination. The specimen removed consisted of three rubbery tumor masses, the largest of which measured about 4.5 by 4 by 3 centimeters in size. The surface was rough, with caseous areas and definite gross calcific deposits. Review of the slides showed the microscopic picture to be identical with that previously described and to be typical of calcinosis.

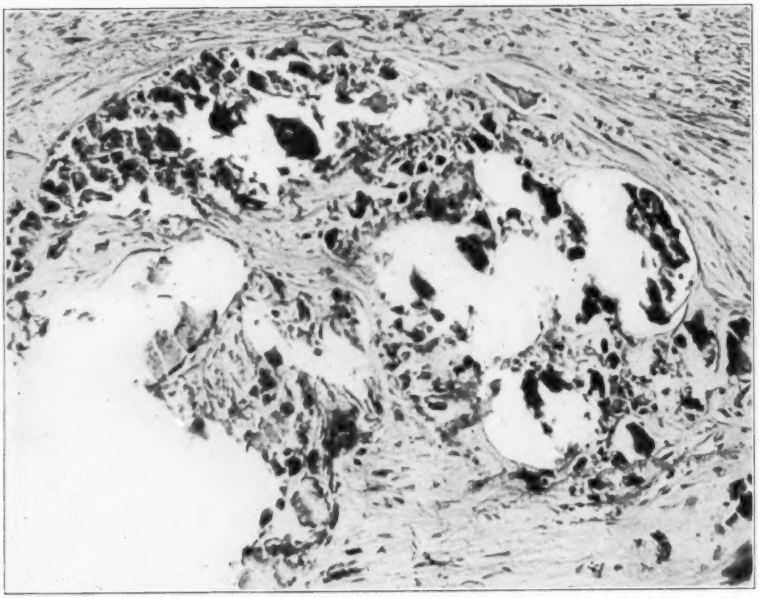

FIG. 2-E

Photomicrograph (× 150) stained with hematoxylin-eosin. Shows foreign-body reaction and calcific deposits in tumor.

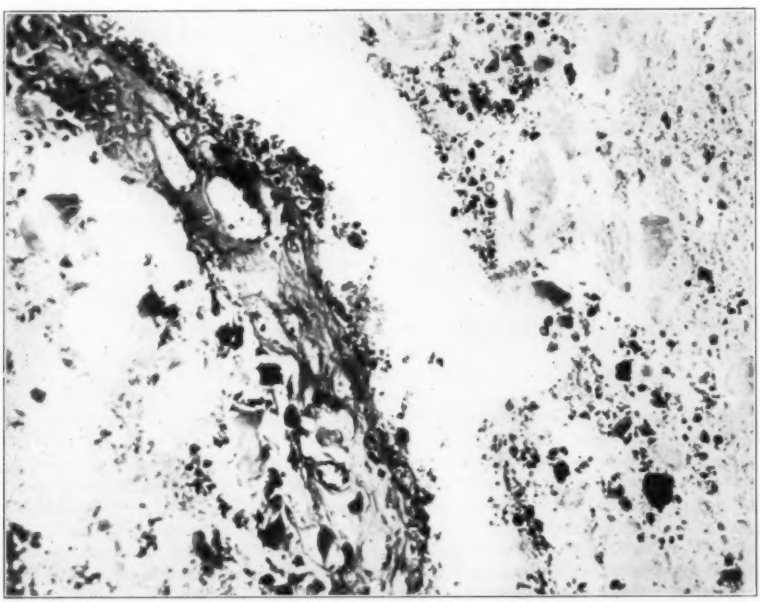

FIG. 2-D

Photomicrograph (× 85) stained with hematoxylin-eosin. Shows part of large cystic area, containing various-sized calcium deposits.

(The original diagnosis from this material by J. M. N. was of multiple periarticular giant-cell tumors.)

After consultation, it was agreed that this patient should have a period of roentgenotherapy over the involved areas. This was given, and two weeks later he was allowed to go home. A total of 1,000 roentgens was given to the left shoulder in preparation for surgical removal of the tumor, but no evidence was found of reduction in size of the mass.

The patient was not seen again until July 24, 1940, when he was admitted to the Lincoln General Hospital in a rather desperate condition. He was extremely emaciated, and had been in bed for several months because of weakness. Recently there had been acute pain in the left hip with increased swelling and fluctuation. During the last few days the pain had become unbearable, and could not be controlled by sedatives. The least movement produced a terrific paroxysm of pain. Since previous drainage had given relief, he desired immediate drainage.

Physical examination was as follows: Pulse 104 and irregular; temperature 101; and respirations 20 per minute. There was marked emaciation. The throat was injected; the tongue was coated; severe dental caries was noted; the gums were pale. The heart was enlarged in the left anterior axillary line. There was a blowing apical systolic murmur, with extension into the axilla. The entire upper portion of the thigh was tremendously swollen; a fluctuating mass could be felt in this region.

The laboratory findings were as follows:

Blood	
Hemoglobin	2.4 grams per 100 cubic centimeters (15 per cent.)
White blood cells	13,050
Polymorphonuclear neutrophils	75
Eosinophils	4
Lymphocytes	20
Monocytes	1
Urine	
pH	5.5
Specific gravity	1.011
Albumin	4 plus
Lymphocytes	1 plus
Erythrocytes	Occasional
Bile	0
Urobilinogen	0

The operative risk was recognized, and two suitable donors for postoperative transfusions were located. Because of the patient's condition, 1,000 cubic centimeters of five per cent. glucose was started with cyclopropane anaesthesia. The pulse was 120 and the blood pressure was 124 systolic and 60 diastolic. An incision for drainage was made through the fluctuating mass. Pus and debris rolled out under pressure, and a large section of the tumor mass was removed rapidly. Suddenly the patient's blood pressure dropped to 60 systolic and 20 diastolic. The wound was quickly dressed and all known restorative measures were applied, but without benefit. Oxygen, transfusion, adrenalin into the heart muscle, caffeine, and coramine were administered, but within an hour after returning to bed the man died.

Today, we realize that preoperative transfusions should have been given. However, the patient's appeals for relief of terrific pain seemed to warrant drainage. Too rapid evacuation of the cavity probably contributed to the collapse. This should have been controlled, had we contemplated such complete degeneration of the tumor.

The surgical specimen removed consisted of a large tumor mass, about 20 by 17.5 by 15 centimeters in size, but partially fragmented. The cut surface showed caseous and calcific material plus purulent debris. The microscopic sections were similar to those previously described, but with evidence of some acute inflammatory reaction. (The original diagnosis by J. M. N. was soft-tissue giant-cell tumor with superimposed inflammatory changes.)

Autopsy was performed in this case (R. D., male, twenty-nine years of age, Autopsy Protocol Lincoln General Hospital No. 1933) in 1940, a short time after removal of the tumor. The gross autopsy report originally listed as the primary findings the soft-tissue giant-cell tumors with secondary ulcerative and inflammatory changes. The gross report also included possible amyloid disease of the liver, spleen, and kidneys; congenital cysts of the kidneys; and fatty changes in the heart.

The microscopic changes, including amyloid stains with crystal violet, revealed amyloid disease of the kidneys, spleen, adrenals, and pancreas. Amyloid deposits were reported in the residual soft-tissue tumors, and it was because of this that subsequent tumors in other brothers were considered as manifestations of amyloidosis.

A complete review of the autopsy material reveals many interesting features. There is indisputable evidence of amyloid disease of the kidneys, spleen, adrenals, and pancreas. However, these changes in no way resemble the peculiar calcific deposits seen in the periarticular tumors (Figs. 2-D and 2-E). The amyloid in the visceral organs is of the usual homogenous type of infiltration around blood vessels, and is without

foreign-body reaction or inflammation. This stain for amyloid is specific for that substance only in a general way, and any amorphous material deposited in tissue will take this stain to a greater degree than the adjacent viable and normal tissues. The ordinary hematoxylin-eosin stains disclose a vast difference in the histological features of the tissues with the amyloid deposits and the original tissues with calcific deposits. Amyloid notoriously evokes no particular reaction in the tissues, while calcium acts as a foreign body and produces the reaction seen in the original periarticular tumors.

It is our opinion that the amyloid disease in the viscera was secondary to the chronic suppuration accompanying the local calcinosis. Some tissues in this patient, particularly the lung, showed definite peribronchial calcific changes without amyloid. In the adrenal, both were probably present as distinct entities.

CASE 3. W. D. This boy, aged twelve, had large tumors on the backs of his elbows, similar to those of D. D. and that removed from R. D. The one on the right was discovered about one year before admission, and that on the left appeared about eight months before. Both had been growing steadily, were about equal in size, and looked much like small apples. There was no limitation of motion and they were not tender, but they were bothersome and disfiguring. Physical examination showed nothing further of an abnormal nature. His temperature was 100, pulse 100, and respirations 22 per minute. The blood pressure was 105 systolic and 75 diastolic.

The laboratory findings were as follows:

Hemoglobin	11 grams per 100 cubic centimeters (70 per cent.)
White blood cells	10,300
Polymorphonuclear neutrophils	52
Bands	3
Eosinophils	8
Basophils	1
Lymphocytes	35
Monocytes	1
Blood urea	26
Urea clearance	93.3 per cent. (normal)

In the Congo red test, 90 per cent. of the dye was retained in the blood, which is within normal limits; no dye was noted in one hour in the urine specimen. The urine was not remarkable. The sedimentation rate was 18 millimeters in one hour (Cutler method). The calcium-phosphorus ratio was 10 to 4.

On May 3, 1941, both tumors were removed; recovery was uneventful. The material removed consisted of three small fragments of tissue, measuring as much as 4 centimeters in diameter. A light creamy "pus" was present in a fibrous and gritty stroma. The review of microscopic sections showed a picture identical with that previously discussed, and typical of calcinosis. (The original diagnosis in this case, by J. M. N., based on studies made in conjunction with the autopsy just reported, was amyloid tumor of soft tissue.)

On July 23, 1945, the boy returned with a large tumor on the lateral aspect of the right hip, directly over the greater trochanter. He had first noted this about six months before, after having been kicked by a horse. The last two months it had increased rapidly in size. It measured approximately 13.8 by 8.8 centimeters and protruded outward under the tense skin, covering about three inches. One could palpate a multilocular, semifluctuating body of the tumor. There was no tenderness and it did not seem to be firmly attached to the underlying structures. Motions of the hip were not limited and there was no limp. Nothing else of an abnormal nature was found on physical examination. There was no evidence of recurrence of the tumors which had been removed from the elbow regions in 1941. X-ray examination of the hip region showed a large fluffy mass of calcium deposit or increased density over the region of the greater trochanter of the right hip (Fig. 3-A). The clinical and laboratory findings yielded nothing significant. On July 27, 1945, through a longitudinal incision, the tumor mass was removed. It extended well up into the glutaeus maximus and down below the level of the lesser trochanter. There was more extension of the process into the muscle substance than in any of the previous tumors which had been removed. It was necessary to resect a considerable amount of muscle substance and to remove the tumor mass completely. The wound healed by first intention and no disability followed.

This specimen afforded the first opportunity for study of material from these cases by one of the authors (F. H. T.), and initiated the review of earlier slides, as described. This mass measured 9.5 centimeters in diameter and was fragmented, showing a peculiar gross tissue of whitish-pink stroma, very firm, with small cavities containing a semimucoid granular and calcific material (Fig. 3-B). There were attached skeletal muscle fragments present, and grossly the tumor appeared to have invaded the muscle. The tumor was tough and cut with increased gritty resistance. Microscopically, the picture was exactly as described in the first case, and was considered a type of calcinosis. The diagnosis was calcinosis, involving periarticular soft tissues of the hip.

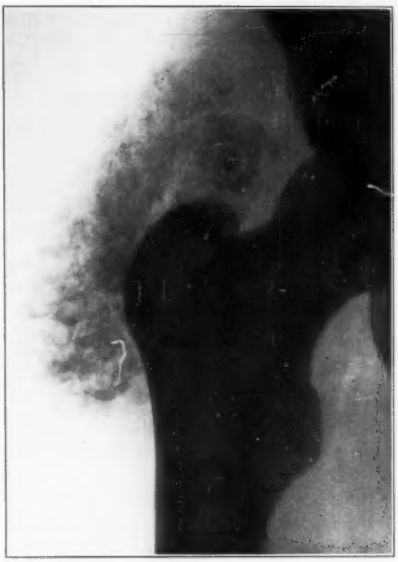

FIG. 3-A

FIG. 3-B

Fig. 3-A: Roentgenogram of tumor of right hip with characteristic findings of tumoral calcinosis.
Fig. 3-B: Gross specimen from hip (9.5 centimeters in diameter before cutting) shows cut surface with fibrous stroma and small cavities containing milky and calcific debris.

On May 27, 1947, we cared for this boy, who had suffered compound, comminuted fractures of the right tibia and fibula, due to having been kicked by a horse. He was convalescing very satisfactorily and there had been no recurrence or evidence of calcified tumors at the original sites or elsewhere. During the preceding two years he had subjected himself to all types of trauma, as he is a "broncobuster" with real ability.

In summary of the pathological data, it appears that the multiple periarticular and soft-tissue tumors in these three patients are identical with one another, and that they are primarily a form of calcinosis. In the one case progressing to death, ulceration to the surface with chronic suppuration occurred, and autopsy revealed definite visceral amyloidosis plus early visceral calcinosis (lungs and adrenals). While it is the authors' opinion that the amyloid disease is secondary, it is nevertheless significant because, to our knowledge, its association with calcinosis has not been reported previously. Also, since so little is known about abnormal calcium deposits, the coexistence of the two may be more than coincidental.

Finally, the nature of the calcinosis itself invites speculation. In the absence of significant disturbances in blood chemistry, a local disturbance is most likely. The possibility of aberrant localization of synovial tissue with a tissue reaction to the secreted foreign material is considered. Also, the possibility of an abnormal synovial fluid in periarticular bursa with the production of a tissue irritant from the synovial membrane might be postulated.

SUMMARY

Three cases of calcinosis of the tumoral type are reported. The significant features are:

1. The three patients with tumoral calcinosis are brothers.

2. The sites of the tumors, as well as the microscopic appearance and laboratory data, were similar.

3. The tumors appeared during adolescence and were self-limited in size, after growing for about one year.

4. Most of the tumors arose near joints in the region of gliding surfaces or bursae, but extended into muscles.

5. The tumors were fairly well defined, lobulated, and fluctuating.

6. They were not accompanied by pain, tenderness, or limitation of motion.

7. Complete removal seems to cure the condition locally, but similar tumors may appear elsewhere.

The fatal ending in the case of R. D. was the result of long-standing infection, due to early secondary infection following drainage, extensive amyloid changes in the viscera, and unfortunate circumstances accompanying his critical condition when final drainage was attempted.

"Tumoral calcinosis" seems to be a distinct entity of the general condition, calcinosis.

REFERENCES

BAUER, J. M., and FREYBERG, R. H.: Vitamin D Intoxication with Metastatic Calcification. J. Am. Med. Assn., **130**: 1208–1215, 1946.

INCLAN, ALBERTO: Tumoral Calcinosis. J. Am. Med. Assn., **121**: 490–495, 1943.

PEDERSEN, JØRGEN: On Calcinosis. Calcinosis Universalis in a Man with Uric-Acid Diathesis and Hypogonadism, and Typical Calcinosis Circumscripta in a Woman. Acta Med. Scandinavica, **113**: 373–394, 1943.

STEINITZ, HERMANN: Calcinosis circumscripta ("Kalkgicht") und Calcinosis universalis. Ergebn. d. inn. Med. u. Kinderh., **39**: 216–275, 1931.

DISCUSSION

OPERATIVE TREATMENT OF SCOLIOSIS

(*Continued from page 106*)

brace; it is not the "Blount" brace. When we presented the basic principles two years ago, the greatest criticism was that one cannot correct a rigid curve as far with the brace as with a bent jacket. That is probably true in some cases. In the material presented just now, it was shown that extreme correction is not usually desirable. In our hands, the brace has never failed to obtain all of the desired correction. It will do everything that the transection jacket does. It is easier for the orthopaedic surgeon to use, and more comfortable for the patient to wear. It will certainly correct the curves which Dr. Cobb has demonstrated. Dr. Schmidt and I, as well as many of our colleagues, are using the Milwaukee brace with increasing satisfaction. When we are sure that all of the "bugs" are out of the method, we plan to publish the technique in detail.

DR. ARTHUR STEINDLER, IOWA CITY, IOWA: First, a point of definition: What is scoliosis? The earmark of scoliosis is the irreversibility of the position of the spine. If the spine is no longer subject to voluntary muscle control, there is evidence of beginning structural changes. I do not admit the term "physiological scoliosis".

Second, scoliosis is a deformity in which the spine penetrates into the thorax by a process of lateral displacement and rotation. It leaves the thorax behind in rotation. I have not heard a word about displacement of the thorax. The thorax is always displaced on the concave side. Correction of the thorax must always be carried out, therefore, by convex-side detorsion.

Third, I almost feel like falling on Dr. von Lackum's neck; not because he mentioned my name, but because after twenty-five years of my preaching about compensation, he has finally come back to it. I started emphasizing compensation and I still take that stand; he started with correction and now comes back to compensation.

What is compensation? It is the development of counter curves, so that realignment occurs between occiput and pelvis. The case showed by Dr. von Lackum, with 100 degrees' deviation of what he called the primary curve, does not show any compensation. The curvature of the body was transmitted and continued through the pelvis and lower extremities. One of the hips was in abduction and the other in adduction,—the earmarks of decompensation. This same principle applies to the anteroposterior curve. If you have a round hollow back and both curves are of equal length and angular value, they are compensated. On the contrary, if the curve includes the pelvis and extends through the lower extremity, the curve includes the entire length of the body. Such a curve is not compensated. It is necessary to make a definite decision as to what constitutes compensation. I do not see how any misconception or confusion can arise, if the definitions are elaborated on simple mechanical lines.

THE ILIOTIBIAL BAND

Its Role in Producing Deformity in Poliomyelitis *

BY CHARLES E. IRWIN, M.D., WARM SPRINGS, GEORGIA

From Georgia Warm Springs Foundation, Warm Springs

In 1926, Yount presented an excellent study of the tensor fasciae femoris and indicated its part in producing deformity of the lower extremities. He pointed out a triad of deformities,—hip-flexion and abduction contracture, knee-flexion contracture, and knock-knee. During the twenty-two years following this classical publication, there has been ample material available to make it possible for one to understand better the role of contracted fascia lata in lower-extremity deformities, and the important part it plays in the severe pelvic and trunk deformities so often seen.

The iliotibial band with its allied structures is probably the greatest deforming factor in lower-trunk and lower-extremity involvement following infantile paralysis. It has been said that this is a fact only in those cases which had had no care, or in which treatment had been inadequate during the acute and early convalescent stages. This is not always true. The author has seen these contractures appear and progress, in spite of the best conservative treatment available to the patient. The importance of these structures as a deforming factor has not been sufficiently emphasized since the original work of Yount.

The iliotibial band is the thickened portion of the fascia lata along its lateral aspect. The fascia lata has an extensive origin. It arises as far posteriorly as the coccyx and sacrum, laterally to the crest of the ilium, and anteriorly to Poupart's ligament and the superior ramus of the pubis. It is composed of two layers,—a superficial layer which covers the glutaeus maximus and tensor fasciae femoris, and a second layer deep to these muscles. It gives attachment to most of the fibers of the glutaeus maximus and to all of the fibers of the tensor fasciae femoris. The fibers of the fascia lata then converge to form the iliotibial band on the lateral aspect of the thigh. It is continuous medially with the lateral intermuscular septum, through which it gains attachment to the linea aspera throughout its length. Distally, it gives origin to the short head of the biceps. As it reaches the level of the knee joint, it again spreads out to become attached to all of the lateral prominences just below the knee, including the head of the fibula. It is important to remember that the iliotibial band lies in a plane anterior and lateral to the axis of the hip joint, and in a plane posterior and lateral to the axis of the knee joint.

Involvement of the muscles attached to this band is responsible for the increased tension under which it is placed during the acute and early convalescent stages of poliomyelitis. Spasm in the short head of the biceps and increased tension in the iliotibial band can be easily demonstrated by an attempt to extend the leg on the flexed thigh. Spasm in the glutaeus maximus can be easily demonstrated by flexing the extended leg on the trunk. If the increased tension in the iliotibial band during the acute or early convalescent stage is not released by adequate conservative care, this tension becomes a progressive contracture.

Treatment indicated for the patient in the acute stage should be continued until the joints of the hip and the knee can be passively carried through their full range of motion in all directions without force, and without pain or discomfort to the patient. When this has been accomplished, the full length of the iliotibial band will have been preserved; and deformities due to its contracture will be less likely to occur.

* Presented at the Instructional Courses of the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1948.

LOWER-EXTREMITY DEFORMITIES

A contracture of the iliotibial band on one side may contribute directly or indirectly to the development of the following deformities:

1. *Flexion and Abduction Contractures of the Hip*

The band occupies a plane lateral and anterior to that of the hip joint. The pelvis is the fixed point from which the femur is flexed and abducted.

2. *Contracture of the Thigh in External Rotation*

For comfort, patients with this deformity maintain the involved extremity in an attitude of flexion, abduction, and external rotation of the hip, flexion of the knee, and equinus and varus of the foot. The external rotators of the hip undergo adaptive shortening to conform to this position.

3. *Genu Valgum*

The tibia will be abducted and may be flexed on the femur. The band continuous with the lateral intermuscular septum gains attachment to the entire shaft of the femur along the linea aspera. The lateral femoral condyle does not project as far distally as the medial condyle in structural knock-knee deformity. It is entirely possible that these bone changes are due to the greater resistance offered by the more dense lateral septum. As the genu valgum increases, the band is placed in a more advantageous position to further increase the deformity. The contracted band exerts a force on the lateral aspect of the joint, similar to that which the taut string exerts on the concavity of an archer's bow.

FIG. 1 FIG. 2

Fig. 1: Varus deformity of the foot caused by the application of a brace to an extremity where tibial torsion was present.

Fig. 2: Functional varus was corrected when thigh portion of the brace had been externally rotated.

Although numerous factors are responsible for inequality of limb length, there is reason to believe that the dense band attached to the femur throughout its length can contribute to the over-all shortening of this long bone. The band crosses both femoral epiphyses and the upper tibial epiphysis. In a growing child, the band tends to become relatively shorter as the femur becomes longer. A tremendous discrepancy may be present in the length of extremities with a short band on one side. If some epiphyseal arrests do not appear to be retarding growth to the extent that is expected, a tight iliotibial band on the opposite side may be a contributing cause.

4. *Knee-Flexion Deformity and External Torsion of the Tibia*

As the deformity increases, the knee may become contracted in flexion, since the band occupies a plane posterior to that of the knee joint. With the knee in a flexed position, the tibia and fibula will rotate externally and the tibial condyles may begin to subluxate on the femur. The fibular head can often be palpated in the popliteal space. This is particularly true if the short head of the biceps is strong.

5. Varus Deformity of the Foot

There are various causes of varus deformity of the foot. One of the most common is an attempt to fit a long brace to an extremity in which external torsion of the tibia is evident. The varus deformity develops in the presence of this torsion, because the axes of the knee and ankle joints do not occupy the same horizontal plane, whereas the axes of these joints in an ordinary walking brace are in the same horizontal plane. When such a brace is placed on an extremity with external torsion of the tibia, and the thigh portion is prevented from externally rotating by a pelvic band, the foot must turn into the varus position to be in line with the knee joint (Fig. 1).

If the thigh portion of the brace is allowed to rotate externally on the thigh, the functional varus deformity will disappear, as the foot can assume its normal relationship to the ankle (Fig. 2). The deformity, at first, is purely functional, due to the brace; but later it undergoes typical structural changes, requiring surgical intervention.

DEFORMITIES OF THE PELVIS AND TRUNK

1. Pelvic Obliquity

The thigh is flexed and abducted in relationship to the vertical axis of the body only when the pelvis is level or is at a right angle to the vertical axis of the trunk. When the extremity on the side of the flexion and abduction contracture is forced into a weight-bearing position (parallel to the vertical axis of the body), the pelvis is forced into an oblique position. The obliquity is now the existing deformity, although it has been caused by contractures below the iliac crest.

A lumbosacral scoliosis must necessarily develop simultaneously with the pelvic obliquity. If the pelvis is held in an oblique position by contractures below the crest, the lateral trunk muscles of the opposite side will contract to conform to the oblique position of the pelvis. Structural changes in the lumbar vertebrae will follow, producing a structural scoliosis.

2. Exaggerated Lumbar Lordosis

When flexion contracture is present on both sides, the entire pelvis is tilted forward, producing exaggerated lumbar lordosis.

TREATMENT

A contracture, or shortening, of the iliotibial band cannot be corrected with conservative stretching and manipulation by the physical therapist; neither can it be overcome by the application of a series of plaster casts by the orthopaedic surgeon. Surgical intervention is indicated, regardless of the age of the patient or the duration of illness. It is impossible to lock the pelvis securely enough to allow a corrective force of any consequence to be exerted on the contracture. The anterior and lateral abdominal muscles on the side of the contracture are the muscles which will undergo stretching by these conservative measures. The pelvis will simply be forced into an oblique and hyperextended position.

A Soutter fasciotomy, the long-accepted operation for the correction of these contractures, is a procedure to be condemned, as numerous recurrences have followed this procedure. It is an ill-advised operation for the following reasons: These deformities are caused, not by contractures of the normal muscle tissues, but rather by shortening or contracture of the intermuscular septa and enveloping fascia. This fact can easily be demonstrated by dividing the contracted fascia covering the normal muscle tissue; even after the cut edges of the fascia retract an inch or more, the normal underlying muscle tissue can be picked up with tissue forceps and found to be in a relaxed condition. Muscles that are partially involved can become shortened, due to contracture of the involved fibrosed muscle tissue scattered throughout the normal muscle fibers, and in this manner can contribute to the severity of the deformity. This explains, in part at least, why these

FIG. 3

FIG. 4

FIG. 5

Fig. 3: The extremity on the side which has been operated upon is held in flexion and abduction. Sufficient traction to level the pelvis is applied through the Kirschner wire incorporated in the cast on the side of the unaffected extremity.

Fig. 4: Fixed skeletal traction. The spine is flat and the pelvis is level. The spica on the side of the unaffected extremity has been completed, locking this segment in as a unit.

Fig. 5: Fixed skeletal traction plus plaster wedging. A double spica is completed after the extremity on the affected side has been adducted and extended until considerable resistance is felt. Additional correction is easily obtained by wedging the involved extremity further into extension and adduction at the hip.

deformities occur in flail extremities and why, in the unilateral cases, these deformities involve the extremity with the greater weakness.

The short fascia and fibrosed muscle tissue extend from the crest of the ilium distally to the head of the fibula. The important thing to remember is that this short fibrous mass can produce as much deformity distally about the knee as it can proximally about the hip. The offending structures must be attacked proximally as well as distally. A fasciotomy for the hip of the Ober type and a Yount fasciotomy for the iliotibial band and lateral intermuscular septum are the operative procedures of choice.

Ober's fasciotomy consists in dividing the fascia and the intervening fibrosed and fascial bands over the sartorius, rectus femoris, and tensor fasciae femoris, as far back as the greater trochanter. Injury to the lateral femoral cutaneous nerve should be avoided.

The author's conception of a Yount fasciotomy is the removal of a block of the iliotibial band (2 to 3 centimeters), division of the lateral intermuscular septum down to the femur, and section of the fascia lata covering the vastus lateralis. This is done about four inches (10 centimeters) above the knee joint.

One should not try to correct completely these contractures on the operating table. In cases with bilateral deformity, the patient should be placed postoperatively on a hyperextended Bradford frame with both lower extremities enclosed in toe-to-groin casts which are attached by a crossbar to prevent external rotation. The deformities have usually been corrected by the time the sutures can be removed. For the postoperative correction of the more severe deformities, wedging in a double spica may be necessary.

For postoperative correction in cases with unilateral deformity, it is first necessary to pass a Kirschner wire through the femur on the unaffected side, just above the condyle. Toe-to-groin casts are applied to both lower extremities, a Kirschner wire being incorporated on the unaffected side. The patient is then placed on a fracture table; the thigh on the side operated upon is held in flexion and abduction. Sufficient traction is exerted on the unaffected side, through the wire incorporated in the cast, to bring the pelvis to a right angle with the vertical axis of the trunk (Fig. 3).

With traction maintained, the body portion of the spica on the unaffected side is finished and allowed to set. The patient now has a single spica, incorporating the trunk, pelvis, and femur on this side. The pelvis is level and the lumbar spine is flat (Fig. 4).

The extremity on the affected side, which has been maintained in flexion and abduction and has not been incorporated in the spica, is internally rotated, extended, and adducted until considerable resistance can be felt. The double spica is now completed by tying this extremity to the single spica already applied to the other side. Additional correction is easily obtained by wedging the extremity further into increased extension and adduction every three to five days (Fig. 5).

The advantages of fixed skeletal traction plus plaster wedging over well-leg traction become apparent when these deformities are more closely analyzed. There is an element of flexion as well as of abduction in these contractures. The flexion element is not apparent as long as the extremity is in abduction.

When the abducted extremity has been adducted toward the mid-line, the flexion contracture becomes evident. The pelvis is tilted downward and forward; the lumbar lordosis is exaggerated. This is the abnormal position of the spine and pelvis when the cast is applied for well-leg traction. This traction will correct the abduction by increasing the distance from the trochanter to the anterior superior spine, with the pelvis rotating on the femoral head. Additional traction, however, will tend to force the lumbar spine into further lordosis, due to the undisturbed flexion contracture.

With fixed skeletal traction, the surgeon begins the correction of abduction and flexion contractures simultaneously; the pelvis is level and the lumbar spine is flat. The trunk, pelvis, and the normal lower extremity are locked and held in their normal positions by the Kirschner wire incorporated in the plaster on the unaffected side.

In long-standing deformities, when the other muscles mentioned are secondarily contracted and contribute to the severity of a tight iliotibial band, a Soutter fasciotomy may rarely be necessary, in addition to section of the iliotibial band. The iliotibial band should always be sectioned, even though a Soutter fasciotomy is indicated. No correction is attempted on the operating table, and the final correction is always obtained by fixed skeletal traction plus plaster wedgings, as outlined previously.

The surgeon who attempts to correct and to fuse a curve in the lumbar spine, when the pelvis is part of that curve, invites disaster if, before doing the fusion, he does not release all contractures below the crest of the ilium which contribute to the deformity. In all knock-knee deformities requiring osteotomy in the supracondylar region, section of the iliotibial band and lateral intermuscular septum should be done at the same time, if the contracture contributes to the knock-knee deformity.

Every severe and disabling deformity following poliomyelitis has an almost insignificant beginning. It is important to be thorough in examination, to recognize these early functional deviations, and to correct them before fixed deformities of paramount importance develop.

REFERENCES

OBER, F. R.: The Rôle of the Iliotibial Band and Fascia Lata as a Factor in the Causation of Low-Back Disabilities and Sciatica. J. Bone and Joint Surg., **18**: 105–110, Jan. 1936.

SOUTTER, ROBERT: A New Operation for Hip Contractures in Poliomyelitis. Boston Med. and Surg. J., **170**: 380–381, 1914.

YOUNT, C. C.: The Rôle of the Tensor Fasciae Femoris in Certain Deformities of the Lower Extremities. J. Bone and Joint Surg., **8**: 171–193, Jan. 1926.

TREPHINE BIOPSY OF BONE WITH SPECIAL REFERENCE TO THE LUMBAR VERTEBRAL BODIES *

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Aspiration biopsy of bone presents the same advantages in differential diagnosis as does aspiration biopsy of soft tissues. Bone biopsy is usually much more difficult, however, because of the technical problem involved in obtaining an adequate piece of material from what is frequently a relatively inaccessible site. In the process of boring through bone, aspirating the specimen, and expressing it by the use of the ordinary needle, there is usually marked distortion of the tissue architecture. This distortion adds to the already difficult problem of pathological interpretation.

Most vertebral-body lesions can be diagnosed adequately by a correlation of clinical, laboratory, and roentgenographic findings. However, the problem of differential diagnosis frequently arises; and, because of the inaccessibility of the vertebral body surgically, the clinician must often be satisfied with a presumptive diagnosis.

* Read before the Orthopaedic Section, New York Academy of Medicine, April 16, 1948.
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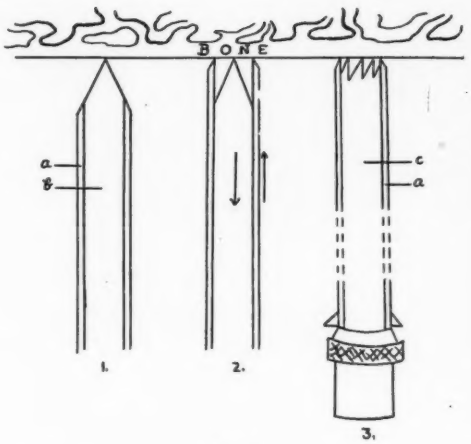

FIG. 1

FIG. 2

Fig. 1: The outer needle (*a*) with stylet (*b*) is inserted down to bone (*1*). The needle is advanced over the stylet to the bone, and the stylet is withdrawn (*2*). The inner saw-toothed biopsy needle (*c*), with hub adapted to fit a quarter-inch hand drill chuck, is inserted into the first needle (*3*). The hub has a knurled handle for finger rotation in the case of soft or cystic lesions.

Fig. 2: A case in which chordoma was shown on biopsy examination. The needle is correctly positioned against the body from which biopsy material is to be obtained. Note the landmarks: The lower tip of the spinous process of the body from which biopsy material is to be obtained corresponds to the level of the transverse process of the body below.

Kirschner, Christiansen, and Ellis used a motor-driven drill with a squared-off needle to obtain biopsy material from soft tissue and bone. Turkel and Bethell introduced an inner needle with a trephine tip, which was rotated by hand within an outer protecting needle, principally for soft-tissue biopsy.

Although accurate diagnosis can frequently be made with tissue obtained from the vertebral body by means of a routine aspirating needle, the tissue usually represents distorted bone fragments and marrow contents. Because of the difficulty of pathological interpretation of these small bits of distorted tissue, a needle was devised which employs the principles of the Turkel needle.

There are several features that make this new needle an excellent instrument for bone biopsy. The beveled tip of the stylet is short and spear-shaped, to minimize the amount of soft tissue obtained before contact with the bone is actually made with the inner biopsy needle (Fig. 1). The inner needle is carefully tooled and has ripsaw teeth, beveled on the leading edge, and projects 3.5 centimeters beyond the outer needle when fully inserted. The inner bore of the needle is straight, to permit easy advancement of the core up the needle. Wedge-shaped tips and inner-threaded tips were tried, but they obstructed the advancement of the core by wedging of bone in the tip of the needle. A most important feature is the use of a hand drill to accomplish rapid, steady, controllable rotation of the needle; this results in a uniform core of bone with little distortion of the architecture within the core. The hub of the needle is made to fit into a quarter-inch hand drill, but also contains a knurled handle to permit hand rotation for soft or cystic lesions.

TECHNIQUE

The technique of insertion of the needle is similar to that employed in paravertebral block of the lumbar sympathetic chain, with the exception that the angle made with the vertebral body is slightly less acute, to prevent the needle slipping off the body anteriorly, and to permit obtaining the maximum amount of tissue from the center of the body. The biopsy is performed under local or light general anaesthesia with roentgenographic control.

FIG. 3-A

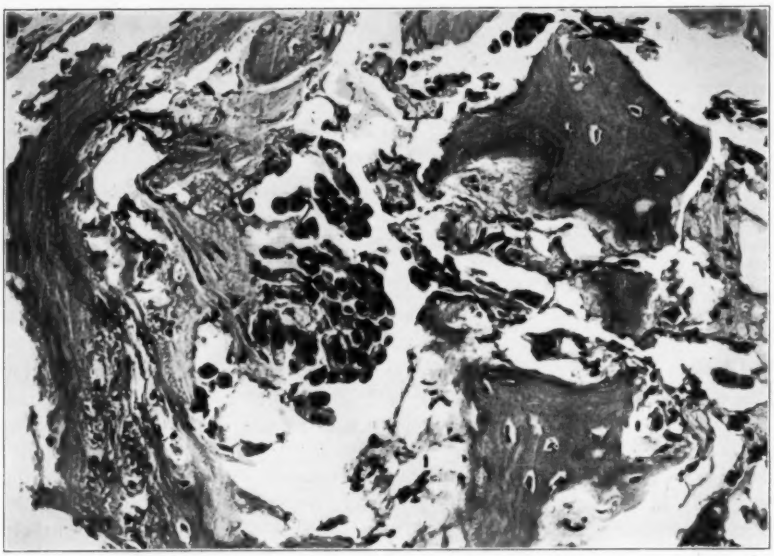

FIG. 3-B

Photomicrographs showing tissue obtained by the needle. Fig. 3-A shows a core of bone from a vertebral body under low-power magnification (× 21), demonstrating undistorted bony architecture. In Fig. 3-B a section of metastatic adenocarcinoma from the vertebral body, under high-power magnification (× 330), demonstrates undistorted details of tumor and bone.

A well-centered postero-anterior roentgenogram is studied in advance because of alterations in landmarks, due to anatomical variations or vertebral collapse. In general, the lower tip of the spinous process of the body to be biopsied will correspond to the level of the transverse process of the body below (Fig. 2). The path of the needle and the paravertebral area are well infiltrated with novocain, a long, fine-gauge needle being used, with the patient in the prone position. A scalpel-point incision is made at the level chosen, about three and one-half fingerbreadths (6 to 7 centimeters) lateral to the mid-line. The first needle, with stylet, is inserted downward and inward at an angle of 45 degrees with the surface of the skin, until the transverse process is encountered. The needle is withdrawn slightly and the angle is changed, so that it glances off the superior border of the transverse process as it is advanced down to the vertebral body. A roentgenogram is taken and, if the needle is directed correctly, as shown in Figure 2, the stylet is removed and the inner cutting-edge needle on a hand drill is inserted. A core is removed by rotating the drill at the desired speed, with controllable directional pressure, depending

upon the consistency of the bone. The size of the core can be regulated by calibrations on the inner needle. When the biopsy has been completed, several turns of the needle are accomplished without advancement, to assure cutting off the core at its base. The inner needle is removed with the core inside, and the core is expressed with a stylet (Figs. 3-A and 3-B). If the tissue is of solid consistency, it remains within the needle and suction is unnecessary. If it is soft or cystic, hand rotation can be employed, and syringe suction is maintained as the inner needle is withdrawn.

The technique of trephine biopsy of bones other than the vertebral bodies is identical to that just described.

DISCUSSION

This technique of trephine biopsy presents several advantages. After removal of the inner needle containing the biopsy core, a long needle can be inserted into the first needle, which is held in place, and any fluid material in the lesion can be aspirated for smear, guinea-pig inoculation, culture, or other laboratory procedure. The presence of the outer needle precludes soft-tissue injury due to rotation of the inner biopsy needle. In addition, by moving the outer needle slightly along the surface of the bone, many cores can be obtained from neighboring areas without reinsertion of the needle.

By approaching the vertebral body less acutely than in the technique of lumbar paravertebral block, the needle strikes the posterolateral aspect of the vertebral body at such an angle that there is very little likelihood of its slipping anteriorly. Nerve-root puncture occurs infrequently, and causes signs of root irritation only momentarily. These disappear as soon as the direction of the needle has been changed.

In view of the frequent distortion of the anatomical landmarks, it is more accurate and simpler, in approaching the vertebral body, to employ the relationship of spinous process to transverse process to vertebral body on the roentgenogram than to use a fixed-angle guide apparatus for all cases, as described by Valls, Ottolenghi, and Schajowicz.

In aspiration biopsy of bones other than the vertebral bodies, this needle is equally useful. Little difficulty was encountered in approaches to such relatively inaccessible areas as the supra-acetabular and the infra-acetabular areas of the pelvis and ischium. Penetration of a thick cortex has been accomplished by the use of the hand drill, and it has never been found necessary to use a motor drill. Most superficial bone biopsies, where roentgenographic control is unnecessary, can be performed under local anaesthesia in the office or at the bedside.

SUMMARY

The relative inaccessibility of the vertebral body for surgical biopsy makes trephine biopsy valuable in this region. By use of the needle described, excellent, adequate undistorted cores of tissue may be obtained, to aid in the differential diagnosis of many lesions.

REFERENCES

Christiansen, Harald: An Aspiration Trepan for Tissue Biopsy. Acta Radiol., **21**: 349–351, 1940.

Ellis, Frank: Needle Biopsy in the Clinical Diagnosis of Tumours. British J. Surg., **34**: 240–261, 1947.

Kirschner: Die Probebohrung. Schweizerische Med. Wchnschr., **16**: 28–30, 1935.

Turkel, Henry, and Bethell, F. H.: Biopsy of Bone Marrow Performed by a New and Simple Instrument. J. Lab. and Clin. Med., **28**: 1246–1251, 1943.

Valls, José; Ottolenghi, C. E.; and Schajowicz, Fritz: Aspiration Biopsy in Diagnosis of Lesions of Vertebral Bodies. J. Am. Med. Assn., **136**: 376–382, 1948.

SURVIVAL AND GROWTH OF AN EPIPHYSIS AFTER REMOVAL AND REPLACEMENT

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In 1946, the author [2] reported the case of a boy, eleven years of age, who had suffered a dislocation of the elbow with a fracture through the neck of the radius and displacement of the head of the radius backward into the elbow joint. The dislocation was reduced by the family physician, and the patient was then brought to St. Louis for treatment of the fracture-dislocation of the head of the radius.

He was operated upon about forty-eight hours after the injury; and the head of the radius, which included the epiphyseal line and a bit of the neck, was found completely free in the posterior portion of the

FIG. 1

Dislocation of the head of the radius. Preoperative and postoperative views.
(Reproduced from article by J. A. Key, which appeared in *The Journal*, **28**: 148, Jan. 1946.)

FIG. 2

Lateral and anteroposterior views of elbow, about thirteen months after operation.
(Reproduced from article by J. A. Key, which appeared in *The Journal*, **28**: 148, Jan. 1946.)

elbow joint. It was lifted out with forceps, placed in a folded towel, and laid upon the instrument table while a bed was prepared for it. It was then replaced on the neck and the elbow was flexed to 90 degrees; the capsule was sutured around the head, the wound was closed, and the extremity was immobilized in a plaster cast, care being taken to disturb the position of the parts as little as possible during the application of the cast. The cast was removed eight weeks after the operation; and the boy was advised to begin to use the arm, but to avoid strain for a few weeks.

He returned thirteen months after the operation for a check-up; it was found that the movements of the elbow were almost normal, there being about 5 degrees of limitation of extension. The roentgenograms at that time (Fig. 2) showed the head of the radius united and in satisfactory position. It was the author's opinion that the head of the radius and the epiphyseal line were living.

The previous report has been criticized by some who think that insufficient time had elapsed for an end-result report, and that the head of the radius looks dead in the reproduction of the roentgenograms (Fig. 2). Fortunately this boy has recently returned to St. Louis, by request, for another examination.

He is now fifteen years old, and at the time of the last examination a little over four years had elapsed since the operation. He has grown rapidly, and is now five feet, eleven and one-half inches tall. The boy plays basketball and baseball on his high-school teams, and states that at no time has he noted weakness, pain, or disability in the elbow. He states that this is his throwing arm and that he is able to throw a baseball as well as other boys on his team.

On physical examination, flexion and extension of the elbow and rotation of the forearm were normal when compared with the uninvolved left upper extremity. There was no evidence of shortening of the radius or of deformity of the elbow or wrist. The only abnormality noted was slight soft crepitus on palpation over the head of the radius, while the forearm was being rotated. Roentgenograms (Fig. 3) show the head of the radius living and united to the neck with slight angulation. The epiphyseal line appears closed. This boy now has an approximately normal right upper extremity.

The author believes that this report affords sufficient evidence to warrant reiteration

FIG. 3

Roentgenograms of the elbow of a boy, fifteen years of age, in whom the head of the radius had been completely removed and replaced at the age of eleven, four years and one month before. The epiphysis has survived and grown at the normal rate. It is possible that some of the head may have died and been replaced. (These x-rays have been reversed.)

of the statement that, in children, epiphyses should be replaced if possible, because they may survive and the bone may grow normally, even though the epiphysis has been completely separated and is without blood supply[1]. In these days of bone banks, this case is of interest because it brings up the perennial question of how much of a bone graft lives; it may constitute some evidence on behalf of the autogenous graft.

REFERENCES

1. KEY, J. A.: Treatment of Fractures of the Head and Neck of the Radius. J. Am. Med. Assn., **96**: 101–104, 1931.
2. KEY, J. A.: Survival of the Head of the Radius in a Child After Removal and Replacement. J. Bone and Joint Surg., **28**: 148–149, Jan. 1946.

ACUTE ANTERIOR DISLOCATION OF THE SHOULDER*

BY TOUFICK NICOLA, M.D., MONTCLAIR, NEW JERSEY

Six years ago, the author reported to this organization on the role of the articular capsule in anterior dislocation of the shoulder. Included in this report were observations based on the pathological findings in five cases of acute anterior dislocation. Since that time, the author has operated upon twenty-two more acute dislocations of the shoulder and has found that the location and extent of the pathological lesion vary in different cases, depending upon the producing force.

A force of hyperabduction will tear the capsule from the neck of the humerus and, if severe enough, will tear part or all of the subscapularis tendon from its attachment to the neck of the humerus (Figs. 1 to 8). If a force of impaction is added while the arm is going into abduction, the capsule and the labrum will tear away from their attachment to the neck of the scapula. The capsule will also tear, in a longitudinal direction, as the head becomes dislocated (Figs. 9 and 10).

FIG. 1

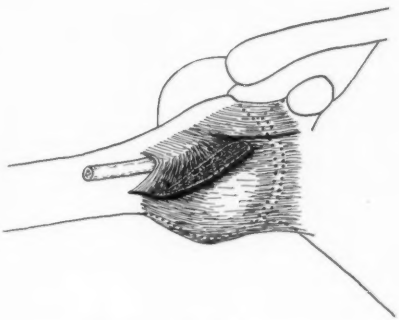

FIG. 2

Fig. 1: Roentgenogram of shoulder in 85 degrees of abduction.
Fig. 2: Position of capsule when shoulder is in 85 degrees of abduction.

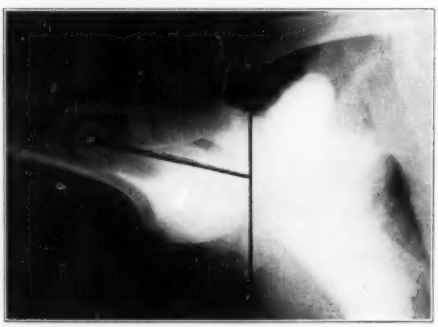

FIG. 3

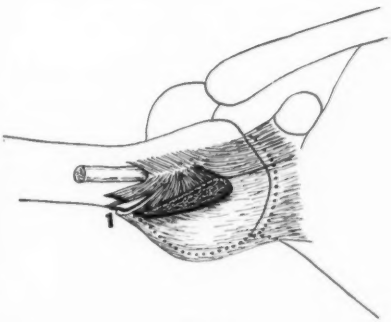

FIG. 4

Fig. 3: Roentgenogram of shoulder in 105 degrees of abduction.
Fig. 4: Capsule (*1*) begins to tear away from neck of humerus when shoulder is in 105 degrees of abduction.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1948.

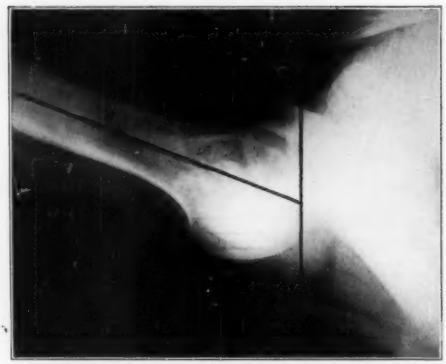

FIG. 5

FIG. 7

Fig. 7: Hyperabduction tears capsule and subscapularis tendon from neck of humerus.

Fig. 8: Capsule and subscapularis tendon torn away from neck of humerus and sucked into joint, covering glenoid cavity. (*1* indicates anterior capsule covering glenoid cavity.)

FIG. 9

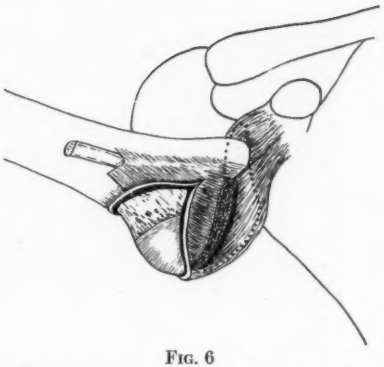

FIG. 6

Fig. 5: Roentgenogram of shoulder in 115 degrees of abduction.

Fig. 6: Capsule and part of subscapularis have torn away from neck of humerus when shoulder reaches 115 degrees of abduction.

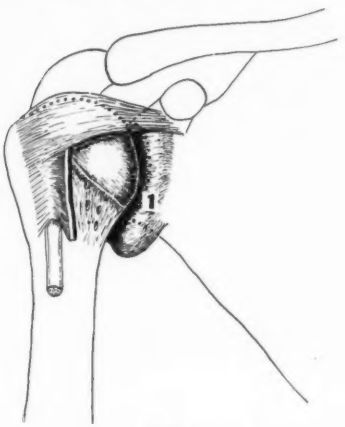

FIG. 8

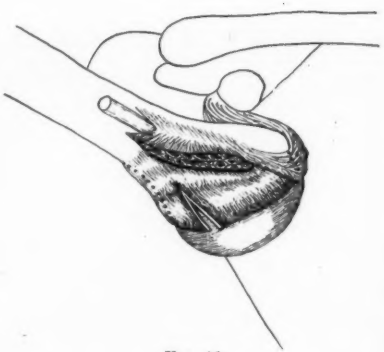

FIG. 10

Fig. 9: Force of abduction and impaction produced by fall on elbow.

Fig. 10: Capsule torn away from rim of glenoid cavity by force of abduction and impaction.

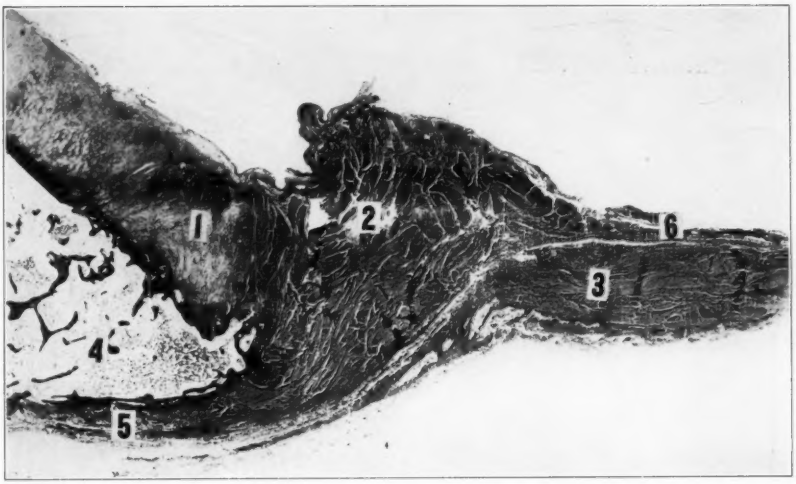

FIG. 11

Section of glenoid cavity, taken at anterior inferior aspect (about four o'clock). *1*, Cartilage covering glenoid cavity; *2*, labrum; *3* and *5*, capsule; *4*, bone of glenoid; and *6*, synovial membrane.

There is still a misconception about the method of attachment of the capsule and labrum to the scapula. Some surgeons think that the capsule and labrum are attached to the rim of the glenoid cavity and that, when they are torn away from this attachment, they do not become reattached. Therefore, we have recurrent dislocation of the shoulder. However, the observations of the author, made in 1941, and those of Fahey and DiCosola, in 1947, show that the capsule and labrum are attached primarily to the periosteum which covers the neck of the scapula (Fig. 11).

The report presented here is based on a study of twenty-seven consecutive cases of acute anterior dislocation of the shoulder.

CASE 1. A school teacher, thirty-three years old, had a stiff shoulder which was manipulated under anaesthesia in order to increase motion. After manipulation, the hand was attached to the head of the bed for five days, during which time the patient complained of severe pain in the shoulder region. When the hand was released, the patient could not bring her arm down to her side. Roentgenograms showed anterior dislocation of the shoulder. After a closed reduction had proved unsuccessful, the shoulder was explored. The anterior capsule and the subscapularis tendon had been torn away from their attachments to the neck of the humerus and were covering the glenoid cavity. After the capsule and the subscapularis tendon had been lifted, it was possible to replace the head in the glenoid cavity. The capsule and the subscapularis tendon were then reattached and, at the end of two weeks, the patient was instructed to exercise her shoulder to prevent stiffness. Seven weeks later the shoulder became redislocated. The patient refused further operation.

CASE 2. A farmer, forty-eight years old, fell between two trucks and his right arm was forced over his head. Roentgenograms showed anterior dislocation of the shoulder. Exploration before reduction disclosed that the head of the humerus was lying under the coracoid process; the capsule and subscapularis had been torn away from the neck of the humerus and were covering the glenoid cavity. The head of the humerus was replaced under the acromion by the use of downward traction and by forcing the arm from the side of the chest wall. It redislocated very easily. It was necessary to lift out the capsule and subscapularis tendon before the head of the humerus could be reduced satisfactorily. No attempt was made to repair the defect, but the shoulder was immobilized for eight weeks in an apparatus which prevented abduction and external rotation. At the end of five years the dislocation had not recurred.

CASE 3. A housewife, aged thirty-nine, was standing on a stool to hang curtains. The stool slipped; she grasped the curtains, and felt something give in her right shoulder. Roentgenograms showed anterior dislocation of the right shoulder. On exploration, the anterior portion of the capsule and the lower half of the sub-

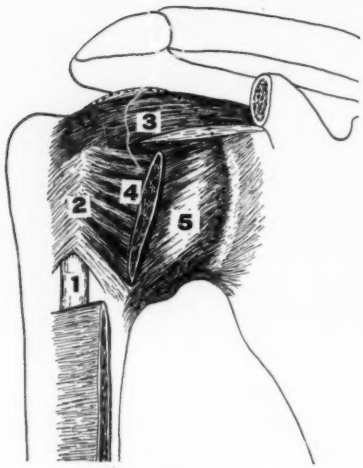

FIG. 12-A

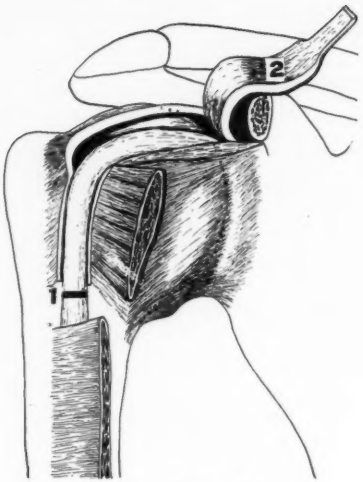

FIG. 12-B

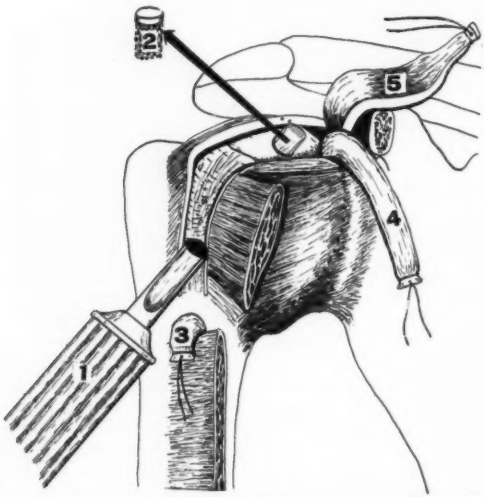

FIG. 12-C

Fig. 12-A: Anterior aspect of shoulder joint.
1, Long head of biceps.
2, Transverse humeral ligament.
3, Coracohumeral ligament.
4, Subscapularis tendon.
5, Anterior portion of capsule.

Fig. 12-B: *1*, Point of division of long head of biceps.
2, Transverse humeral and coracohumeral ligaments, reflected up to base of coracoid.

Fig. 12-C: *1*, Gouge in position through head of humerus.
2, Plug from head of humerus.
3, Distal portion of long head of biceps.
4, Proximal portion of long head of biceps.

scapularis tendon were found to have been torn away from the neck of the humerus. No attempt was made to repair the capsule or the tendon, but the dislocation of the shoulder was reduced by traction and adduction, with the fist high in the axilla. Then the shoulder was immobilized for seven weeks. To date, after three and a half years, there has been no recurrence.

CASE 4. A woman, thirty-eight years old, had a stiff shoulder, which was manipulated under anaesthesia and direct vision. The abduction manipulation tore the capsule away from the neck of the humerus in a longitudinal direction. When abduction was continued, the head of the humerus became dislocated. The head was replaced by downward traction and adduction, with the fist high in the axilla. The shoulder was immobilized for eight weeks. At the end of a year there had been no recurrence, but the motions in the shoulder were still restricted about one-half in all directions.

CASE 5. A basketball player, while shooting a ball into a basket, had his arm pushed up farther. He felt something tear and give way in his left shoulder. Roentgenograms showed an anterior dislocation. Exploration disclosed that the capsule and part of the subscapularis tendon had been torn away from the neck of the humerus. No attempt was made to repair the capsule or the subscapularis tendon. The patient resumed athletics at the end of three weeks, and one month later this shoulder became redislocated when he was trying for a basket. At reoperation, the capsule was found to be loose, although healed and intact. The labrum had

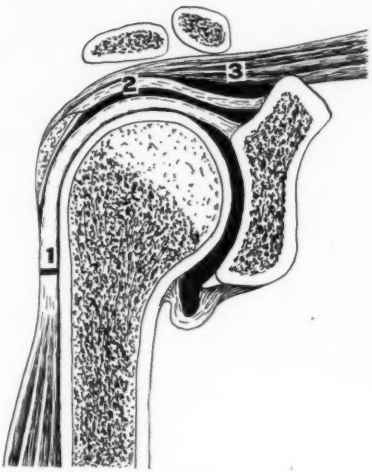

FIG. 12-D

Frontal section of shoulder.
1, Long head of biceps.
2, Coracohumeral ligament.
3, Supraspinatus muscle.

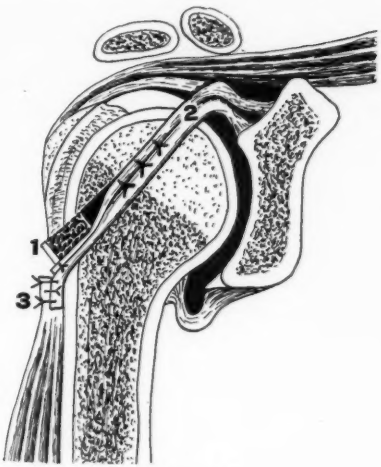

FIG. 12-E

Frontal section of shoulder.
1, Plug of bone in position.
2, Coracohumeral ligament and long head of biceps have been passed through head of humerus.
3, Long head of biceps has been sewed together.

torn loose from the rim of the glenoid, but the capsule was still attached to the neck of the scapula. This case was treated by anterior capsulorrhaphy and by passing the long head of the biceps and the coracohumeral ligament through the head of the humerus (Figs. 12-A to 12-E). No recurrence has been reported for two years.

CASE 6. A truck driver was thrown from his truck and landed on his left elbow. Roentgenograms of the left shoulder showed a fracture of the greater tuberosity and dislocation of the head of the humerus. The elbow was lacerated. Exploration revealed that the capsule and labrum had torn away from the rim of the glenoid. The glenoid was not fractured. The head was replaced by downward traction and adduction, with the fist in the axilla. No attempt was made to suture the capsule or to reattach the greater tuberosity. A

FIG. 13-A

FIG. 13-B

Fig. 13-A: Shoulder has been reduced by traction and adduction, with fist high in the axilla.
Fig. 13-B: Showing apparatus which prevents redislocation by restricting abduction and external rotation.

TABLE I

SUMMARY OF FINDINGS IN TWENTY-SEVEN CASES

Case No.	Age	Occupation	Causative Force	Pathological Findings	Immobilization (*Weeks*)	Results	Remarks
1	34	School teacher	Hyperabduction	Capsule torn from humerus	2	Redislocation	Refused reoperation
2	47	Farmer	Hyperabduction	Capsule torn from humerus	8	Satisfactory	
3	39	Housewife	Hyperabduction	Capsule torn from humerus	7	Satisfactory	
4	38	Housewife	Hyperabduction	Capsule torn from humerus	8	Satisfactory	
5	17	Playing basketball	Hyperabduction	Capsule torn from humerus	3	Redislocation	
6	29	Truck driver	Abduction plus impaction	Capsule torn from scapula	8	Satisfactory	
7	17	Playing basketball	Abduction plus impaction	Capsule torn from scapula	8	Satisfactory	
8	16	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
9	19	Playing football	Uncertain	Capsule torn from scapula	8	Redislocation	Reoperation
10	17	Playing hockey	Uncertain	Capsule torn from scapula	8	Satisfactory	
11	16	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
12	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
13	19	Playing football	Uncertain	Capsule torn from scapula	7	Redislocation	Reoperation
14	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
15	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
16	15	Playing basketball	Uncertain	Capsule torn from scapula	6	Redislocation	Refused reoperation
17	17	Playing basketball	Uncertain	Capsule torn from scapula	8	Satisfactory	
18	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
19	15	Playing basketball	Uncertain	Capsule torn from scapula	8	Satisfactory	
20	19	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
21	19	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
22	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
23	16	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
24	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
25	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
26	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
27	19	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	

special apparatus was applied to restrict abduction and external rotation (Fig. 13-B). There has been no recurrence for three years.

CASE 7. A basketball player fell on his right elbow and dislocated his right shoulder. Exploration showed that the capsule and the labrum had been torn from the rim and neck of the scapula. No repairs were made. The upper extremity was immobilized for eight weeks. No recurrence has been reported over a period of three years.

In the next twenty cases, all high-school students ranging in age from fifteen to nineteen years, the descriptions of the injuries were uncertain. In all of them the capsule and the labrum had been torn from the rim and the neck of the scapula. No attempt at repair had been made. Except in three cases, none had further recurrence after their activities had been restricted for eight weeks by an apparatus which prevented abduction and external rotation. In two of these three cases, a second operation was performed; the long head of the biceps and the coracohumeral ligament were passed through the head of the humerus, and the capsule was reattached to the rim of the glenoid, as described by Bankart.

The author has found, by observation under direct vision, that the best method of reducing dislocations is by downward traction and adduction, with the fist in the axilla (Fig. 13-A).

In no case in this series of twenty-seven was the axillary nerve injured.

CONCLUSIONS

Perhaps no far-reaching conclusions should be drawn from this small series of twenty-seven cases of acute anterior dislocation of the shoulder. However, it seems fair to say that:

1. The pathological findings in acute anterior dislocation of the shoulder are not the same in every case.

2. The injury depends upon the causative force. Hyperabduction will tear the capsule from the neck of the humerus and, if severe enough, will tear part or all of the attachment of the subscapularis tendon away from the humerus. If a force of impaction is added as the arm goes into abduction, the labrum glenoidale and the capsule will tear from the neck of the scapula, also in a longitudinal direction.

3. Reduction of acute anterior dislocations is accomplished with the least amount of trauma by traction and adduction, with the fist high in the axilla.

4. Most recurrent dislocations of the shoulder are the result of too early and too vigorous use of the shoulder, before the capsule has had time to heal and to reattach itself to the neck of the humerus or the neck of the scapula. An eight-week period of immobility in an apparatus which will prevent abduction and external rotation gives the best results.

REFERENCES

BANKART, A. S. B.: The Pathology and Treatment of Recurrent Dislocation of the Shoulder-Joint. British J. Surg., **26**: 23–29, 1938.

FAHEY, J. J., and DICOSOLA, MICHAEL: Pathology of the Shoulder after Experimental Dislocation at Autopsy. Scientific Exhibit, Am. Acad. Orthop. Surg., Chicago, January 1947.

NICOLA, TOUFICK: Anterior Dislocation of the Shoulder. The Rôle of the Articular Capsule. J. Bone and Joint Surg., **24**: 614–616, July 1942.

TRAUMATIC POSTERIOR (RETROGLENOID) DISLOCATION OF THE HUMERUS *

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Anterior dislocation of the head of the humerus from the glenoid is a relatively common injury, and is usually recognized promptly and given adequate treatment. Posterior dislocation of the humeral head to the retroglenoid position, however, is relatively infrequent. It is often unrecognized, and may not be given adequate care until some weeks after the injury, when its treatment becomes a difficult surgical problem and the prognosis for normal function is materially decreased.

The purpose of this paper is: (1) to present eleven patients with posterior dislocation of the shoulder, one of whom had a bilateral dislocation; (2) to review the clinical and roentgenographic signs of posterior dislocation of the shoulder; and (3) to present a method of treatment which, in the authors' experience, has yielded the most satisfactory results.

Many reports in the literature of posterior dislocation of the shoulder present luxations which have been the sequelae of obstetrical injuries and have existed from birth. This type of dislocation will not be discussed here; only those posterior dislocations which have followed acute trauma or violent muscle contraction in convulsive seizures will be considered.

Early mention of posterior dislocation of the shoulder in the literature calls attention to the fact that it occurs during epileptic seizures. Sir Ashley Cooper, in 1839, reported a patient who suffered a retroglenoid dislocation while in an epileptic convulsion. Thomas, in a review of the literature of posterior dislocation of the shoulder, stated that Malgaigne, in 1855, reported thirty-four patients from the literature and three patients from his own practice with posterior dislocation, seven of whom were epileptics. Thomas further stated that Malgaigne had found this type of dislocation to be first recorded in 1804.

Thomas, in 1937, reported seven patients with posterior dislocation of the shoulder. Four of the dislocations occurred during epileptic seizures. One patient's arm was wrenched by a purse-snatcher; another was injured when he fell, while playing tennis; another came into contact with a high-tension wire and fell from a pole. Thomas encountered only four cases in over 6,000 roentgenographic examinations of the shoulder.

The authors, in a review of 260 consecutive dislocations of the shoulder in a large hospital over a period of seven years, found only four instances of posterior dislocation, an incidence of 1.5 per cent.

SUMMARY OF PATIENTS STUDIED

Eleven patients with posterior dislocation of the shoulder were studied. One of these patients suffered a bilateral posterior dislocation, making a total of twelve shoulders in which the head of the humerus was displaced to the retroglenoid position (Table I). All of the patients were males. The youngest was nineteen years of age, and the oldest was eighty-two.

The cause of the dislocation in seven of these patients was external trauma. In three patients the cause of the dislocation was an epileptic convulsion; one of these patients suffered a bilateral dislocation. One patient suffered a luxation as a result of violent muscle contraction initiated by contact with a live electric wire, which suggests that this type of dislocation might be an occasional complication of electric-shock therapy.

Four patients had posterior dislocation of the humerus without fracture. In eight dislocated shoulders there was concomitant fracture. This varied in degree from a trough

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fracture in the head to the separation of a large fragment of bone, comprising the greater portion of the head. In most instances, the fracture consisted of the avulsion of a small fragment of bone from the inferomedial segment of the head. This fragment usually included only a small piece of the articular cartilage of the head.

A diagnosis of the true nature of the injury was made in only five instances by the first physician who saw the patient. In six patients in this group (54 per cent.), the diagnosis of posterior dislocation was not made until the lapse of many days or weeks after the injury, despite the fact that roentgenograms had been obtained. In one instance, a correct diagnosis was not arrived at until four months after the injury; and in another, not until six months had passed. The coincidental fracture may have had some bearing on these errors.

Treatment was dependent upon the promptness with which the diagnosis was made. One patient, in whom the diagnosis was not made for four months, refused treatment, despite the fact that his shoulder was painful and useless. Three other patients, in whom the diagnosis was made late, were subjected to open reduction. In one of these three, a Nicola tenosuspension was done at the same time. Despite this additional surgery, the humeral head became redislocated to the anterior position, as it did in one other patient upon whom a late open reduction was done. Four patients, in whom an early diagnosis was made, were treated by prompt closed reduction and immobilization in a Velpeau bandage. One senile patient, in whom the diagnosis was missed for two months, was treated in the same manner. Of the five patients treated by closed reduction and external immobilization, spontaneous and insidious redislocation occurred in three. In two of these patients, this complication was unrecognized and a late open reduction was necessary. In another patient subjected to closed manipulation, a partial fracture of a large fragment was completed, necessitating open operation. In all, seven patients, with eight dislocated shoulders, had open reduction.

Two patients were treated by a new technique, consisting of transfixing the humeral head to the acromion process with cruciate wires, projecting through the skin over the acromion. One of these patients had a single dislocation which was treated a few hours after injury. After a closed reduction, the humeral head and acromion were transfixed. The other patient had a bilateral posterior dislocation, and did not receive treatment until twelve days after the epileptic seizure which had caused the dislocation. Closed reductions were attempted, but failed. An open reduction of each shoulder was done, and, with the head held in normal relation to the glenoid, transfixion wires were inserted through the acromion process into the head; they were left projecting through the skin over the acromion. The forearms were then held in front of the chest by bandages. The end result was excellent in the first patient treated by reduction and transfixion; he had a normal, painless shoulder six months after injury. The second patient treated by the transfixion technique obtained good results in both shoulders. He had only a slight restriction of abduction and external rotation. He was free from pain, and at the end of nine months had returned to manual work. No complications or redislocations occurred in these three shoulders.

One other patient, treated promptly by closed reduction and external fixation, obtained a good result. Four patients had fair results with rather marked loss of abduction and of external and internal rotation, and their shoulders were painful after exercise. Three of these patients were subjected to late open reduction, and one, a man of eighty-two years, had a late closed reduction. Each of two of these patients with fair results had a concomitant fracture.

In four patients the final result was poor; the shoulder was painful and there was a total loss of glenohumeral motion. One of these patients was untreated. Two underwent late open reduction, with subsequent dislocation to the subcoracoid position. Another suffered a concomitant fracture of a large section of the head, which was removed at a late open reduction.

TABLE I

FINDINGS IN ELEVEN PATIENTS WITH POSTERIOR DISLOCATION OF THE SHOULDER

Case No.	Name	Age and Sex	Etiology	Concomitant Fracture	Time from Injury to Diagnosis	First Treatment	Complication	Treatment Subsequent to Complication	Findings at Operation	Period of Immobilization	Results
1	R. L.	32 M.	Trauma. Picture fell on shoulder.	None	10 hours. First physician.	Closed reduction; wire transfixion to acromion				3 weeks; Velpeau bandage	Excellent. Normal shoulder 6 months after dislocation.
2	C. W.	66 M.	Epileptic convulsion	*Right* Large fragment from inferomedial margin of humeral head	4 days. Treatment delayed until twelfth day.	Closed reduction; failure. Open reduction; wire transfixion to acromion.			Organizing hemorrhage; large fragment broken out of inferomedial side of humeral head.	3 weeks; Velpeau bandage	Good. Abd. restr. 10°. Ext. rot. restr. 30%.
				Left Large fragment from inferomedial margin of humeral head	4 days. Treatment delayed until twelfth day.	Open reduction; wire transfixion to acromion.			Organizing hemorrhage; large fragment broken out of inferomedial side of humeral head.	3 weeks; Velpeau bandage	Good. Abd. restr. 15°. Ext. rot. restr. 35%.
3	J. C.	35 M.	Trauma. Fell from moving locomotive.	Small fragment from medial aspect of head, adjacent to shaft	4 months					4 months; concomitant compound fracture of elbow, same arm	Poor. Painful shoulder. Total loss of glenohumeral motion.
4	J. V.	19 M.	Trauma. Fell from moving truck.	Trough fracture in head	6 months	Open reduction and Nicola tenosuspension, 7 months after injury	Postoperative dislocation of head to anterior position	None	Dense scar. Fibrillation of articular cartilage. Trough fracture in humeral head.	8 weeks; aeroplane cast	Poor. Painful shoulder. Total loss of glenohumeral motion.
5	S. E.	64 M.	Trauma. Fell down cellar steps.	Trough fracture in head	6 hours. First physician.	Closed reduction. Velpeau bandage.	Redislocation in Velpeau bandage. Not recognized.	Open reduction; on aeroplane splint 9 months after injury. Dislocated anteriorly.	Dense scar. Fibrillation and erosion of articular cartilage. Trough fracture.	10 weeks after operation; aeroplane splint	Poor. Painful shoulder. Total loss of glenohumeral motion.

TABLE I (*Continued*)

cated anteriorly.

TABLE I (*Continued*)

6	P. J.	20 M.	Trauma. Automobile accident.	Small fragment from inferomedial margin of head	6 hours. First physician.	Closed reduction. Velpeau bandage.	Redislocation in Velpeau bandage. Not recognized.	Open reduction 5 weeks after injury	Dense scar. Small bone fragment at inferior margin of glenoid. Defect in head.	6 weeks after operation; aeroplane splint	Fair. Abd. restr. 40°. Ext. rot. restr. 50%. Int. rot. restr. 25%.
7	N. H.	32 M.	Convulsive seizure from electric shock	None	5 months	Open reduction and immobilization, 6 months after injury			Dense scar. Marked degeneration of articular cartilage. Groove in head.	6 weeks; aeroplane splint	Fair. Abd. restr. 45°. Ext. rot. restr. 50%. Int. rot. restr. 50%.
8	G. C.	37 M.	Epileptic convulsion. Had brain tumor.	Large fragment comprising ⅓ of articular surface of head	20 days. Consultant.	Closed reduction, unsuccessful		Open reduction, 25 days after injury	Organized hemorrhage. Large loose fragment, comprising ⅓ of head, removed.	6 weeks	Poor. Painful shoulder. Total loss of glenohumeral motion.
9	D. O'L.	82 M.	Trauma. Fell down steps.	None	2 months	Closed reduction 2 months after injury. Velpeau bandage.	Redislocated in Velpeau bandage	Closed reduction. Arm immobilized in extreme int. rot. with forearm behind back for 3 weeks.		5 weeks	Fair. Abd. restr. 50°. Ext. rot. restr. 60%. Int. rot. restr. 20%.
10	H. T.	36 M.	Epileptic convulsion	Large fragment comprising most of head	12 hours	Closed manipulation	Large fragment of head fractured; most of head behind glenoid	Open reduction, 17 days after injury. Fragment wired to upper end of shaft and head.	Extensive hemorrhagic infiltration of tissues. Large loose fragment of head behind glenoid.	8 weeks	Fair. Abd. restr. 35°. Ext. rot. restr. 30%. Int. rot. restr. 30%.
11	J. S.	43 M.	Trauma. Arm twisted.	None	24 hours. First physician.	Closed reduction. Velpeau bandage.				3 weeks	Good. Abd. restr. 10°. Ext. rot. restr. 20%.

Abd. restr. = abduction restriction. Ext. rot. restr. = external-rotation restriction. Int. rot. restr. = internal-rotation restriction.

FIG. 1-A

FIG. 1-B

FIG. 1-C

FIG. 1-D

Roentgenograms, taken in four cases, show various types of fractures which may occur with posterior dislocation of the shoulder.
Fig. 1-A: Large fragment from inferomedial segment of head.
Fig. 1-B: Fracture of large segment of head.
Fig. 1-C: Fracture of lesser tuberosity.
Fig. 1-D: Small fragment from inferomedial segment of head.

PATHOLOGICAL FINDINGS

Detailed knowledge of the gross pathological changes in traumatic posterior dislocation of the shoulder is lacking. This hiatus in our knowledge results from the fact that: (1) the lesion is infrequent; (2) when recognized early, open operation is rarely necessary; and (3) in the patients who have late surgical repair, the initial soft-tissue damage is obscured by dense fibrous-tissue repair.

The degree of gross disarrangement of the humerus and glenoid depends upon the violence of the force producing the injury. Cadaver experiments show that this dislocation can be produced by forced internal rotation of the arm in adduction. It is probable that in accidents there is a forcible upward thrust on the humerus as well. In those posterior dislocations which result from moderate violence, such as occur from muscle contraction in the epileptic and in ordinary falls, the head of the humerus lies beneath the acromion process, with the anatomical neck abutting against the posterior rim of the glenoid fossa. The lesser tuberosity of the humerus lies on the glenoid fossa. If there is a marked upward

thrust in the violence producing the injury, the head of the humerus may be forced more posteriorly under the spine of the scapula.

It is obvious that the extent of the soft-tissue damage will depend upon the force producing the dislocation. Moullin and Keith, in 1904, concluded from cadaver experiments that the ligaments and capsule were not injured, but that the dislocation was due to a separation and displacement of the glenoidal labrum. Observations of more value concerning the soft-tissue damage have been made by Rowe and Yee; Robertson and Stark; and Hindenach. These authors have all described the surgical treatment of recurrent posterior dislocation of the shoulder, which was the sequela of an original acute traumatic posterior dislocation. Rowe and Yee, in two patients, found the capsule separated from the neck of the scapula, and satisfactorily relieved the recurring dislocation by reattaching the capsule to the posterior glenoid margin after the manner described by Bankart for recurrent anterior dislocation. Robertson and Stark operated upon three patients with posterior dislocation. If a lax capsule was found posteriorly, relief of the chronic dislocation was effected by plicating and reattaching the capsule to the posterior margin of the glenoid. Hindenach found a loose capsule in one patient, and treated the condition by a posterior bone block. Both Hindenach and Rowe and Yee cite instances of patients who had not been relieved of recurring posterior dislocation of the shoulder by a Nicola type of operation. In the cases reported by these authors, the glenoidal labrum was not found to be detached, although Rowe and Yee noted erosion of its posterior inferior surface. It seems probable from these observations, therefore, that, in acute posterior dislocation of the shoulder, there is a tear in the posterior capsule or an avulsion of the posterior capsule from the neck of the scapula.

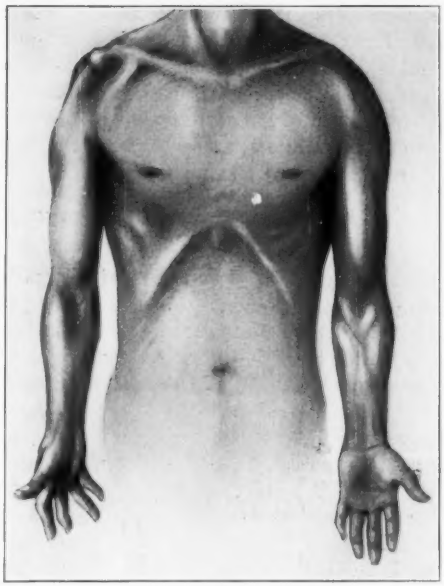

FIG. 2

Drawing of clinical appearance of posterior dislocation of shoulder, showing prominent coracoid process and anterior margin of acromion process; bulge of humeral head posteriorly and flattened deltoid; partial internal rotation of humeral condyles; and inability of patient to supinate back of hand flush to table.

Damage to the bone and articular cartilage of the humeral head varies with the violence producing the dislocation (Figs. 1-A, 1-B, 1-C, and 1-D). In those dislocations resulting from a minimal amount of violence, there may be only an eroded area in the articular cartilage of the humeral head. A vertical trough type of fracture may appear where the soft cancellous head of the humerus comes against the more dense glenoid rim. The lesser tuberosity of the humerus may be separated from the shaft, or a fragment of bone may be avulsed from the humeral head at its junction with the shaft. When the trauma producing the dislocation is severe and the force continues after the head has become wedged back of the glenoid rim, a complete fracture of the neck of the humerus may result, so that the proximal end of the shaft is pulled up over the face of the glenoid, with the head alone lying posteriorly. Other bizarre patterns of fracture may result when the force producing the dislocation is long and continuous.

Injury to nerve trunks does not accompany posterior dislocation, as the excursion of the head of the humerus is not great and it does not directly contuse the nerves or

stretch them. Its direction of dislocation is away from, rather than toward, nerve trunks.

Extensive hemorrhage and infiltration of soft tissues with blood follows this injury, and marked swelling is common. When these dislocations are unrecognized and late open reduction is done, there is marked fibrosis about the humeral head and the glenoid, so that identification of structure is difficult. In those late dislocations associated with fracture, extensive calcification may be present in the soft tissues, and new-bone formation may be present about any fragments.

CLINICAL PICTURE

In the early case of acute posterior dislocation of the shoulder, and also in the old unrecognized case of retroglenoid dislocation, there is no difficulty in diagnosis. The diagnosis is not obvious, however, during the period of swelling produced by extensive extravasation of blood under the deltoid muscle.

In the acute injury before swelling develops, and also in the old unrecognized case, the appearance of the shoulder is quite striking, especially with the patient lying supine. Abnormal prominence of the coracoid process and of the anterior margin of the acromion is present, with flattening of the deltoid muscle belly (Fig. 2). At the posterior margin of the acromion process, where the deltoid normally begins to flatten, there is a prominent globular bulge. This bulge, under the posterior margin of the acromion, can be felt to be the head of the humerus. The condyles of the elbow are in a position of moderate internal rotation. With the patient supine, the forearm cannot be supinated, so that the dorsum of the hand lies flush with the table, as a result of the loss of external rotation in the shoulder. No glenohumeral motion can be elicited, all motions of the humerus moving the scapula.

ROENTGENOGRAPHIC FINDINGS

Posterior dislocation of the shoulder is frequently missed, because of inadequate roentgenographic examination of the shoulder and because of unfamiliarity with the normal shoulder. Anteroposterior roentgenograms of the normal shoulder present a decidedly different picture with the humerus in external rotation than with the humerus in internal rotation. When the humerus is in external rotation, the greater tuberosity is seen prominently in profile, forming the lateral margin of the head; and the lesser tuberosity is just medial to it. There is also a half-moon shadow on the medial contour of the humeral head, where the shadow of the glenoid is superimposed on the humerus. The lower third of the glenoid cavity is covered by the medial border of the humeral head.

In a posterior (retroglenoid) dislocation of the humeral head, the humerus is in extreme internal rotation (Figs. 3-A, 3-B, and 3-C). Various authors have called attention to changes appearing in the anteroposterior roentgenogram. Bonadeo Ayrolo noted loss of the sharp outline of the greater tuberosity and the disappearance of the half-moon shadow of the superimposed glenoid and humerus. Rendich and Poppel called attention to the fact that, in a posterior dislocation, the lesser tuberosity of the humerus forms the medial border of the roentgenographic shadow of the humeral head, and also that the lower third of the glenoid may be exposed in the anteroposterior roentgenogram of a posterior dislocation. Mynter pointed out that, in an anteroposterior roentgenogram of a patient with posterior dislocation, the greater tuberosity lay "directly under and behind the coracoid process". These are all valuable signs and, when present, certainly suggest a derangement of the normal glenohumeral relationship. However, the normal variations in contour of the head of the humerus make them unreliable. In addition, many of these changes can be simulated if an anteroposterior roentgenogram is taken with the humerus in extreme internal rotation, or with the elbow supported in a Velpeau bandage.

The definite and unmistakable diagnosis of posterior dislocation of the shoulder is made by obtaining both anteroposterior and lateral roentgenograms (Fig. 4). The lateral roentgenogram is best obtained by holding the plate over the top of the shoulder and

directing the ray into the axilla (Figs. 5-A, 5-B, and 5-C). This requires moderate abduction of the humerus, but is generally possible without too great discomfort. A less satisfactory lateral view may be obtained by directing the ray through the thorax, with the uninjured arm over the head and the plate on the lateral aspect of the injured shoulder.

In the lateral (axillary) roentgenogram of a posterior dislocation, the humeral head is seen to lie posterior to and outside the glenoid cavity, and to be widely separated from the coracoid process. In an anterior dislocation of the humeral head, the lateral roentgenogram shows the head anterior to the glenoid, but, in contrast to a posterior dislocation, the head is close to, or snugged up against, the coracoid process.

Anteroposterior stereoroentgenograms of the shoulder, when viewed by a person with well-developed stereopsis, reveal the posterior dislocation. Except by a roentgenologist who daily views stereoroentgenograms, the posterior dislocation is apt to be missed. The shoulder joint has very little depth, and does not lend itself well to stereoroentgenography.

FIG. 3-A

TREATMENT

Successful treatment of posterior (retroglenoid) dislocation of the shoulder depends upon three factors: (1) early recognition of the condition; (2) prompt reduction of the humeral head to its normal relationship with the glenoid; and (3) maintenance of the reduction until the capsular structures have healed.

In the first few hours after the injury,

FIG. 3-B

FIG. 3-C

Anteroposterior roentgenograms of shoulder.

Fig. 3-A: Normal shoulder in external rotation with prominent outline of greater tuberosity; semilunar shadow of humerus superimposed on glenoid; and lower third of glenoid covered by humerus.

Fig. 3-B: Posterior dislocation with loss of sharp outline of greater tuberosity; lower third of glenoid is uncovered. Semilunar shadow has not disappeared.

Fig. 3-C: Normal shoulder in internal rotation, showing loss of shadow of greater tuberosity; lesser tuberosity is in glenoid fossa.

FIG. 4

Anteroposterior roentgenogram of posterior dislocation of shoulder, taken on day of injury, showing loss of outline of greater tuberosity, loss of semilunar shadow on medial side of head, and partial bareness of lower third of glenoid. This patient also had compound fracture of elbow, and the posterior dislocation of the humeral head was overlooked.

reduction is easily effected, with anaesthesia adequate to overcome muscle spasm. Gentle traction on the humerus, with the elbow flexed, and simultaneous gentle manipulation to increase the internal rotation, combined with pressure on the head of the humerus, cause the head to fall into its normal relationship to the glenoid. The reduction, however, is unstable; and dislocation easily recurs as a result of motion or may result spontaneously from muscle spasm, even though the arm is immobilized. Of four patients treated by closed reduction and bandaging the arm to the side, spontaneous redislocation occurred in three. The position of greatest stability after reduction is one of internal rotation of the humerus. In one of these patients in whom a redislocation occurred, it was possible to maintain the second reduction by immobilizing the humerus in extreme internal rotation, with the forearm bandaged behind the back for three weeks (Figs. 6-A and 6-B). This is a very awkward, disabling, and uncomfortable position to maintain for a long period of time.

The following method has been used by the authors to ensure maintenance of the reduction in two patients with three dislocations of the shoulder. It has been found to be safe and comfortable.

The first patient was a man, thirty-two years old, who suffered a posterior dislocation of the left shoulder as a result of trauma (Fig. 7-A). He was subjected to a closed reduction ten hours after the injury. With the patient under anaesthesia, the head of the humerus was easily repositioned; however, with the forearm over the abdomen, the head became redislocated. The shoulder was again easily reduced. With the humeral head held in normal relation to the glenoid by pressure back of it, and with the forearm in front of the abdomen, two wires were drilled through the intact skin over the acromion and through the head of the humerus in a cruciate fashion. The ends of the wires were left projecting through the skin over the acromion (Fig. 7-B). The wires were left in place for three weeks, with the arm held to the side in a Velpeau bandage; they were then removed and physical therapy was instituted (Figs. 7-C and 7-D). This patient did not have a concomitant fracture, and five months after injury he had normal motion and muscle power in the shoulder and was taking part in athletics.

The second patient was a man, sixty-six years old, who suffered bilateral posterior

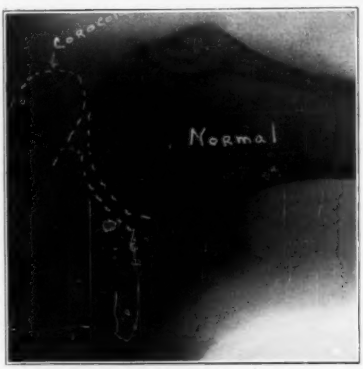

FIG. 5-A

FIG. 5-B

Lateral (axillary) roentgenograms of shoulder, taken with arm abducted, plate on top of shoulder, and ray directed into axilla.

Fig. 5-A: Normal shoulder, with humeral head in glenoid fossa.

Fig. 5-B: Posterior dislocation, with humeral head posterior to glenoid fossa and remote from coracoid process.

Fig. 5-C: Anterior dislocation, with humeral head in front of glenoid fossa and snugged up against coracoid process.

FIG. 6-A: Posterior view of humerus in position of extreme internal rotation, necessary to prevent redislocation in one patient.

Fig. 6-B: Photograph of arm in Velpeau bandage behind back to maintain internal rotation.

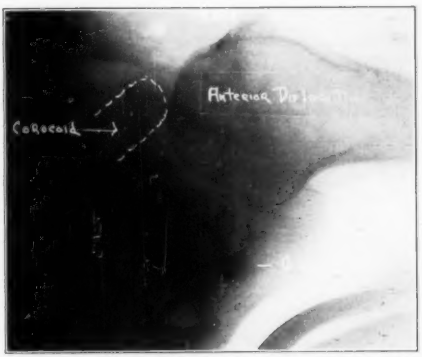

FIG. 5-C

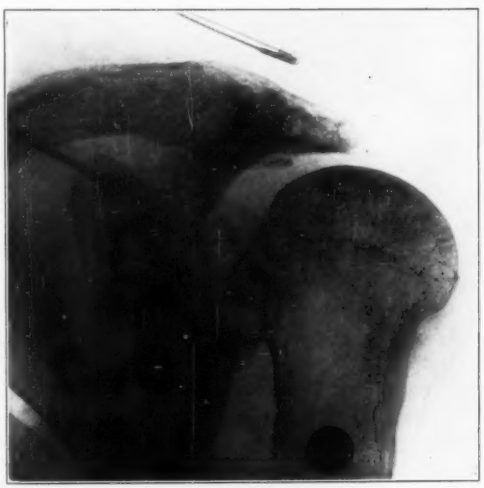

FIG. 6-A

FIG. 6-B

dislocation of the shoulder in a convulsive seizure. There was a concomitant avulsion fracture of a fragment from the inferomedial segment of each humeral head. The condition was

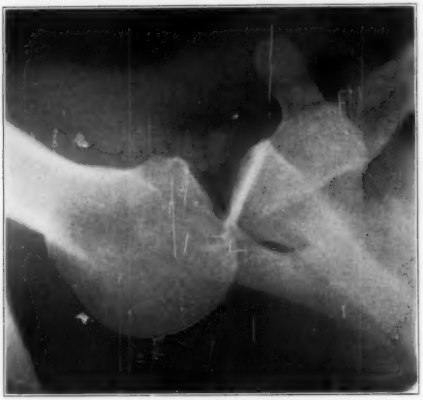

FIG. 7-A

FIG. 7-B

Roentgenograms of thirty-two-year-old man who suffered posterior dislocation of shoulder without fracture.

Fig. 7-A: Lateral (axillary) view. (X-ray has been reversed.)

Fig. 7-B: Anteroposterior roentgenogram after reduction, with humeral head transfixed to acromion process by cruciate wires.

FIG. 7-C

FIG. 7-D

Anteroposterior and lateral (axillary) roentgenograms taken six weeks after reduction. The cruciate transfixion wires have been removed.

not recognized immediately, and the patient did not receive treatment until the twelfth day after injury. An attempt at closed reduction was unsuccessful, and open reductions were done on both shoulders at the same time, anaesthesia being used.

At operation, two large, loose fragments of bone, one of which had been fractured from each humeral head, were removed. With the shoulder capsules exposed, it was impossible to find any position in which the humeral heads were stable in the glenoid cavities. The head of each humerus was held in normal relationship to the glenoid, the elbow being flexed and the forearm being placed over the abdomen. Two wires were then drilled, in cruciate fashion, through the top of each acromion process and through the head of each humerus, transfixing the humeral heads to the acromion processes. The incisions were closed and the arms were loosely bandaged in front of the abdomen, with the elbows flexed. During the three weeks that the wires were left in place, the patient was comfortable. At the end of three weeks the wires were removed by the ends, which projected through the skin over the acromion. Each arm was placed in a sling, and physical therapy was started.

This patient recovered a good range of motion in both shoulders. Nine months after

the injury he returned to heavy work. He had loss of abduction of 10 degrees and a 30 per cent. loss of external rotation in each shoulder.

This procedure is simple, comfortable for the patient, and avoids the possibility of spontaneous redislocation of the head of the humerus.

Treatment of an old unrecognized retroglenoid dislocation of the shoulder requires open reduction. It has been stated by Thomas that good function may be expected in an old unreduced posterior dislocation, due to the formation of a new fossa on the scapula. This statement does not seem logical. All patients in this group with old unreduced dislocations complained of pain down the arm to the elbow, and none had any useful glenohumeral motion.

If the dislocation has been unrecognized for an appreciable period of time, widespread fibrosis of the pericapsular structures is always present. Extensive dissection is necessary to mobilize the humeral head. After the head has been freed, a position of stability in the glenoid is always difficult to find. Wire transfixation of the humeral head to the acromion should be used.

In this group of patients, four were subjected to late open reduction. In two of these patients an anterior dislocation resulted, which might have been avoided had acromiohumeral transfixion been used. A Nicola tenosuspension failed to prevent the anterior dislocation in one patient.

Arthrodesis of the shoulder was not resorted to in this group of patients. Arthrodesis should probably be done in a posterior dislocation of very long standing, in a young individual, when the articular cartilage of the humeral head and glenoid fossa is so severely damaged that a satisfactory joint is improbable.

PROGNOSIS

Posterior dislocation of the shoulder, uncomplicated by fracture, when recognized early and treated promptly and adequately, can be expected to result in normal recovery of motion in the glenohumeral joint. Those posterior dislocations which have a concomitant avulsion fracture or trough fracture will also yield a satisfactory glenohumeral joint when recognized early and treated adequately. However, moderate loss of abduction and rotation should be anticipated if a fracture is present.

It is probable that, despite prompt and adequate treatment, recurrent posterior dislocation of the shoulder will develop in a few patients. Posterior dislocation of the shoulder, which is unrecognized and comes to treatment weeks after the injury, requires open surgical intervention. The result is likely to be poor, with marked loss of motion in the glenohumeral joint and a painful shoulder, unsuited for strenuous activity.

CONCLUSIONS

1. Posterior dislocation of the shoulder is an infrequent injury. It may result from trauma or from convulsive seizure.

2. Because of the infrequency of this injury, and because of the failure to obtain both anteroposterior and lateral (axillary) roentgenograms of the shoulder joint, the dislocation is frequently unrecognized for a long period of time.

3. Prompt recognition and treatment of posterior dislocation of the shoulder by closed manipulation yield excellent results.

4. Even with early prompt reduction, however, the replacement is unstable and there is great danger of spontaneous redislocation.

5. The danger of redislocation can be avoided by the simple expedient of transfixing the reduced humeral head to the acromion process with cruciate wires. This does not require an open operation.

6. Failure of early recognition necessitates open operative intervention. The results of late treatment are poor.

REFERENCES

Bonadeo Ayrolo, A.: Sobre un caso de luxación posterior recidivante de la articulación escápulohumeral. Rev. de Ortop. y Traumatol., **3**: 188–208, 1933.

Cooper, Astley: On the Dislocation of the Os Humeri upon the Dorsum Scapulae, and upon Fractures near the Shoulder Joint. Guy's Hosp. Rep., **4**: 265–284, 1839.

Hindenach, J. C. R.: Recurrent Posterior Dislocation of the Shoulder. J. Bone and Joint Surg., **29**: 582–586, July 1947.

Moullin, C. W. M., and Keith, Arthur: Notes on a Case of Backward Dislocation of the Head of the Humerus Caused by Muscular Action. Lancet, **1**: 496, 1904.

Mynter, Herman: Subacromial Dislocation from Muscular Spasm. Ann. Surg., **36**: 117–119, 1902.

Rendich, R. A., and Poppel, M. H.: Roentgen Diagnosis of Posterior Dislocation of the Shoulder. Radiology, **36**: 42–45, 1941.

Robertson, Ross, and Stark, W. J.: Diagnosis and Treatment of Recurrent Dislocation of the Shoulder. J. Bone and Joint Surg., **29**: 797–800, July 1947.

Rowe, C. R., and Yee, L. B. K.: A Posterior Approach to the Shoulder Joint. J. Bone and Joint Surg., **26**: 580–584, July 1944.

Thomas, M. A.: Posterior Subacromial Dislocation of the Head of the Humerus. Am. J. Roentgenol., **37**: 767–773, 1937.

DISCUSSION

Dr. Harrison L. McLaughlin, New York, N. Y.: I would like to emphasize one point brought out by Dr. Nicola's paper. In two of the twenty-seven cases (between 7 and 8 per cent.), the dislocation resulted from manipulation of a stiff shoulder. Several years ago, Dr. Neviaser showed the damage that manipulation could do to the shoulder mechanism. In our Clinic, a great deal of satisfaction was experienced by the disruption of what we took to be adhesions when a stiff shoulder was manipulated. Manipulation was done in a small series with the shoulder exposed to direct vision, and we found to our surprise that what we had interpreted as a disruption of adhesions was actually disruption of the normal structures of the shoulder. Manipulation of the shoulder is a dangerous procedure, followed by uncertain results; it should be approached with caution, and, when done, it should be carried out with great gentleness.

I must disagree wholeheartedly with Dr. Nicola's final conclusion that most recurrent dislocations of the shoulder result from too early and too vigorous use of the shoulder before the capsule has had time to heal and to reattach itself to the neck of the humerus or the neck of the scapula. He stated that the best results followed an eight-week period of immobilization. In the last twenty cases he reported, the pathological lesion was identified. These shoulders were immobilized for eight weeks and in three of them, or 15 per cent., the dislocation recurred. It seems to me that, rather than proving the point, he has adequately demonstrated that prolonged immobilization will not prevent recurrence. This has been substantiated by our own investigations, which suggest that recurrence depends upon the primary damage to the shoulder structures resulting from the original trauma. It is because of variations in the detail of this injury that no single operation will cure all cases of recurrent dislocation of the shoulder.

Dr. Wilson and Dr. McKeever have done well in demonstrating the frequency with which the diagnosis of posterior dislocation is missed. The single early case which we encountered, however, did not require any method, such as the transfixion wires advocated by these authors, in order to maintain reduction.

Dr. Nicholas J. Giannestras, Cincinnati, Ohio: My experience is limited to one case of recurrent posterior dislocation of the shoulder. This was seen while in the Armed Services, and the following procedure was carried out: After exposure through the posterior approach, as described by Stark, the capsule was found to be torn from the glenoid, and by internal rotation the shoulder could be dislocated at will. The capsule was accordingly sutured to the edge of the glenoid process with interrupted cotton sutures; but, in order to maintain reduction and eliminate tension upon the capsule, it was necessary to hold the shoulder in a position of external rotation. Therefore, after closure of the muscular and cutaneous layers, the extremity was held against the side of the thorax in external rotation with the elbow in complete flexion. It was immobilized in this position for four weeks by the use of adhesive tape and flannel bandages. At the end of this time active motion and physical therapy were instituted; and when this patient was last seen, sixteen months after operation, he had complete recovery of motion.

I appreciate the fact that the method advocated by Dr. Wilson and Dr. McKeever makes security doubly certain by the use of the transfixion wires. I should like to ask, however, if they do not feel that, with the extremity held in complete external rotation, sufficient stability could not have been achieved by immobilization in the acute cases which they reported, thereby obviating the use of the transfixion wires; and, in those cases requiring surgery, whether a posterior approach would not have been the better one.

We, who perform the manoeuvre of Kocher, recognize that the gentle external rotation of the arm is the secret to successful reduction, and that replacement of the head occurs while one is externally rotating the arm.

(*Continued on page 180*)

THE TREATMENT OF RECENT DISLOCATIONS AND FRACTURE-DISLOCATIONS OF THE SHOULDER

BY HENRY MILCH, M.D., NEW YORK, N. Y.

Recent interest in dislocation of the shoulder has been largely devoted to treatment of the recurrent type of lesion. The acute dislocation has been taken for granted, and treatment by the manipulation which Kocher described in 1870 is still recommended as the method of choice. While it represented a distinct advance in its time, the method should now be discarded as dangerous and unphysiological.

Although Cubbins and his associates insist that the biceps tendon offers the chief obstruction to reduction of the dislocated shoulder, the resistance has generally been attributed to the tonic contraction of the subscapularis muscle. Stretching of this muscle with consequent release of the humeral head is the primary objective of Kocher's manoeuvre. Theoretically, it would seem to offer a satisfactory, although brutal, solution to the problem; but the danger lies in the fact that fracture of the shaft of the humerus may be the inadvertent sequel. Almost invariably the fracture line is oblique, running from below the lesser tuberosity upward and outward toward the tip of the greater tuberosity. The humeral head and lesser tuberosity constitute the smaller fragment; the shaft and the greater tuberosity constitute the larger fragment. The constancy of this effect must be attributed to the stress exerted by external rotation of the whole arm against the internal rotatory action of the subscapularis, acting upon the lesser tuberosity. Where the magnitude of this force exceeds the strength of the bone, fracture takes place.

In order to avoid this danger, the writer suggested a method which appears to be almost identical with the method attributed to Sir Robert Jones [6] for the treatment of fracture-dislocations of the shoulder; but, where Jones was concerned primarily with aligning the humeral shaft with the axis of the dislocated head, this method has a deeper justification in the anatomical arrangement of the shoulder-girdle musculature. It is the only method in which the antagonism of individual muscles can be overcome, and in which the force used to overcome muscle pull is in the same direction as that needed to effect reduction.

In the so-called "anatomical position", with the humerus at the side, the direction of the various muscles around the shoulder girdle seems to be completely haphazard (Fig. 1). Some run upward and outward, others run downward and outward, while still others run either directly upward or downward. The resultant of the shoulder-girdle muscles, acting synergistically, is directed principally in a medial direction. With the arm in the anatomical position, this resultant exerts its maximum effect at a large angle, transverse to the longitudinal axis of the bone. The force which must be employed to conquer the resistance of the subscapularis must, at the same time, be large enough to overcome the medially acting components of the other muscles. When the tensile strength of the bone is inadequate to meet this stress, fracture results.

When the arm is placed in the overhead or fully abducted position, an entirely different situation is created. From wherever they arise, whether from in front or in back, all the shoulder muscles run directly upward to be inserted into the humerus or into the axis of the extended upper extremity. In a general manner, all these muscles can be roughly divided into three or four groups. Each of these may be considered as lying upon the surface of separate cones, the apices of which all lie upon a straight line. This straight line is collinear with the axis of the arm and its extension, the forearm (Fig. 2).

The innermost and shortest of these cones is formed by the subscapularis, the supraspinatus, the infraspinatus, and the teres minor. Together, their insertions into the head

of the humerus form the musculotendinous cuff, described by Codman. The second of these groups comprises the latissimus dorsi, the teres major, and the pectoralis major. The apex of this larger and more superficially situated conical group is placed more distally upon the shaft of the humerus. The third group consists of the deltoid and the coracobrachialis. The fourth and longest group is made up of the biceps and the triceps brachii, which insert into the radius and ulna, respectively.

Of all the positions which the humerus may assume, the overhead position is the only one in which all these muscles run in the same general direction. The resultant of the shoulder muscles is coaxial with the humerus, and the transverse or fracturing component

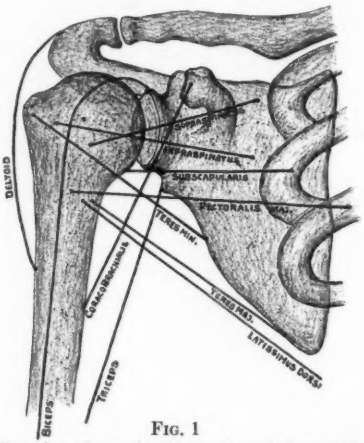

FIG. 1

Drawing of arm in the "anatomical position" with the course of the perihumeral muscles inked in black. Note angle which adducted humerus makes with axillary border of scapula.

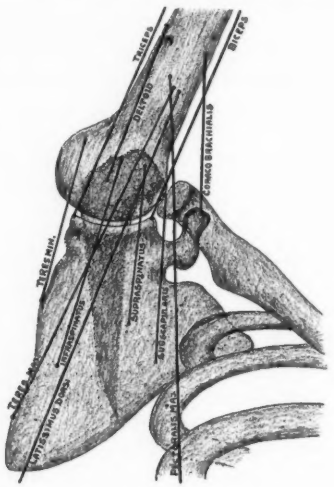

FIG. 2

Fig. 2: The same arm in complete overhead abduction. The scapula has rotated on the chest. The humerus is collinear with the axillary border of the scapula. All the perihumeral muscles fall into four groups of cones, the apices of which all lie in the axis of the humerus.

is reduced to zero. Phylogenetically, this is significant, because the overhead attitude is the position of arboreal brachiation. This is the position in which the resultant of the total muscular effort acts to oppose the downward force of gravity, which tends to tear the trunk away from the limb-clutching arms. It is the only position in which a single force, exerted along the axis of the humerus, is accurately directed to overcome each and all of the muscle actions at the same time. For this reason, it has been chosen as the position in which reduction of dislocation of the shoulder should be undertaken, in preference to the anatomical position employed by Kocher.

The manoeuvres employed have been previously described as follows:[5]

"The patient lies in the supine position, while the surgeon takes his position on the side of the dislocation. In a right sided dislocation the surgeon places his right hand upon the patient's right shoulder, so that the fingers find firm support on the top of the shoulder, while the thumb is braced against the dislocated humeral head. . . . The right hand fixes the head as the left hand gently abducts the arm into the overhead position. . . . During this maneuvre the head of the humerus is supported so that it cannot move from its dislocated position. As a consequence, instead of moving downward as the arm moves upward, the head rotates in place. In this manner the tendency to further stretch already stressed nerves is obviated. . . . Once the arm has been brought into complete abduction in this overhead position, all cross-stresses exerted by all the muscles have been elimi-

nated; the head can be gently pushed over the rim of the glenoid and the dislocation reduced. . . ." (Fig. 3).

The application of the method to acute dislocation, whether associated with fracture or not, is illustrated in the following cases:

CASE 1. E. K., housewife, aged seventy-seven, was first seen April 25, 1940. Four days before, she had fallen and suffered "a subcoracoid dislocation of the shoulder, associated with a fracture of the greater tuberosity of the humerus". An unsuccessful effort had been made to reduce the dislocation.

On April 25, the patient was admitted to the hospital for a reduction under general anaesthesia. Just before this was started, a final attempt to reduce the dislocation was made. The patient's arm was slowly brought into the completely overhead position. On several occasions, when the patient became fearful, progress was stopped, and the patient was soothed and cajoled into indolent cooperation. Once the arm had been brought into complete abduction, the head was gently pushed into the glenoid fossa. All clinical signs indicated complete reduction, and this was confirmed by the roentgenogram. A Velpeau bandage was applied for several days. On April 27, the patient was discharged with her arm in a sling. Motion was restricted for a matter of several weeks, but thereafter the patient gradually resumed her usual activities without any disability.

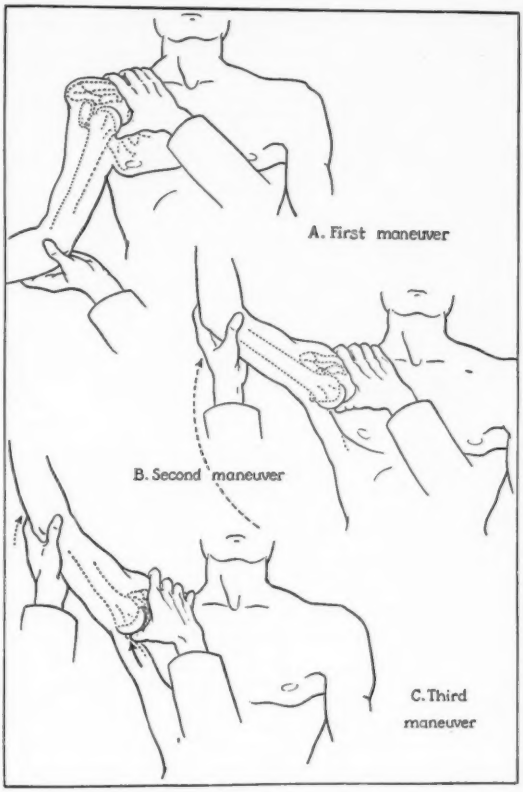

FIG. 3

Steps in the reduction of dislocation of the right shoulder by the overhead abduction-traction-pulsion method. (Reproduced from *Surgery*, **3**: 739, 1938.)

CASE 2. M. K., housewife, aged sixty-four, was seen on September 21, 1942. Early that morning, she had fallen and suffered a subcoracoid dislocation. A local physician had unsuccessfully attempted to reduce this dislocation under general anaesthesia. Some hours later the patient was brought to New York.

The appearance of the arm was typical, and there was no evidence of nerve injury. The roentgenogram disclosed a subcoracoid dislocation of the proximal end of the humerus, associated with a comminuted fracture of the greater tuberosity of this bone. There was outward displacement of the free fragments.

Because of the previous failure of attempted reduction under general anaesthesia, it was believed that great difficulty would be met in reducing this dislocation. Nevertheless, it was determined to make one effort by use of the method under discussion. No anaesthesia was employed. The head of the humerus was fixed, while the arm was elevated with the greatest gentleness. When the arm had reached the overhead position, reduction was accomplished immediately, and even without the necessity of pushing the head over the glenoidal labrum. The patient experienced prompt relief of pain, with immediate restoration of the range of motion. She was given a sling and was permitted to be up and about, but was cautioned against excessive abduction of the arm. A roentgenogram taken on the following day was reported as showing "correction of pre-existing luxation of the humerus", with excellent alignment of the fragments at the site of the comminuted fracture of the greater tuberosity. Three days later, on September 26, it was noted that the patient was actively moving the arm. There was no evidence of brachial fixation or nerve injury. On the following day, the patient was discharged to her home in Connecticut.

The following case is of special interest because of the length of time which had elapsed before closed reduction by manipulation was successful. Many careful surgeons

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 3, J. R. Subcoracoid dislocation of right shoulder, after six weeks. Note calcification in tissues along outer side of the humeral neck.
Fig. 4-B: After closed reduction.

believe that after the lapse of three to four weeks, manipulative reduction, presumably by the Kocher method, is fraught with unusual danger of fracture. After four to six weeks have passed, an unreduced dislocation of the shoulder was considered by Campbell to present a positive indication for open operation in practically all cases. This was not found to be necessary in the following instance:

CASE 3. J. R., housewife, aged seventy-six, was first seen on November 18, 1945. She gave a history of a fall on her outstretched right arm on October 22, 1945. She was taken to a hospital in Florida, where an attempt at reduction was made under general anaesthesia. Despite this, the patient continued to complain of pain so severe that she had to be given hypodermic medication. At the end of two weeks she was discharged to the care of her family physician, but he referred her back to the hospital. The patient was then given an intravenous anaesthesia, and another attempt at reduction was made. This, too, appears to have been unsuccessful, and roentgenograms taken on November 14, 1945, still showed a "subcoracoid dislocation" (Fig. 4-A). The patient thereupon came to New York.

During her trip north, the patient contracted a cold; and upon her admission to the hospital she presented signs of inflammation at the bases of both lungs posteriorly. Because of the presence of the pulmonary signs, the medical consultant advised against surgical procedures. Therefore, it was not until November 28 that the patient could be given a general anaesthetic.

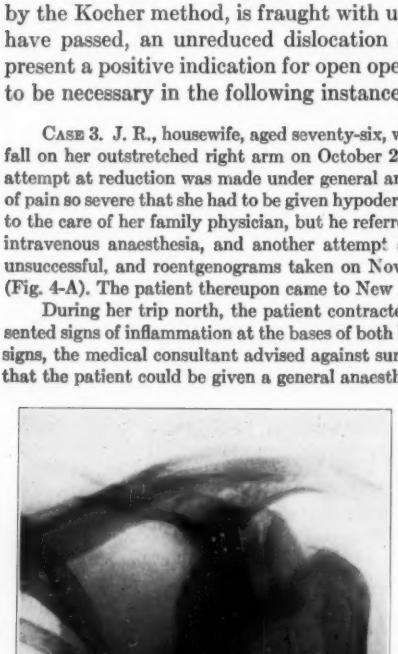

FIG. 5-A

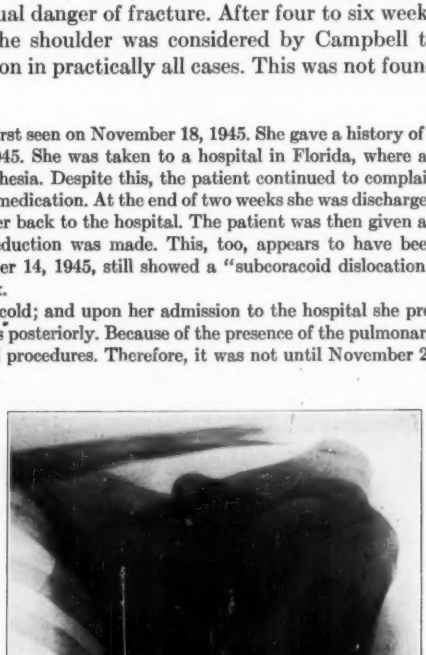

FIG. 5-B

Fig. 5-A: Case 4, R. M. Fracture-dislocation of left shoulder.
Fig. 5-B: After closed reduction.

To avoid the possibility of fracture or damage to the neurovascular structures, the arm was abducted with great care. No serious difficulty was experienced in getting the arm into the overhead position, but even strong pressure against the head did not effect reduction. At this point the shoulder was braced and, while gentle traction was exerted upon the abducted arm, firm pressure was maintained against the head of the humerus. Almost as soon as the combined traction and pulsion was applied, the head of the humerus slipped over the glenoidal rim and the arm could be brought to the side in a normal manner.

A postreduction roentgenogram (Fig. 4-B) was reported as showing almost complete correction of preexisting subcoracoid dislocation of the humerus. In the soft tissues external to the proximal extremity of the humerus, there was an ossifying process. The patient made an uneventful recovery and was discharged from the hospital on December 9, 1945, with a fairly satisfactory range of motion. Under physical therapy, mobility was gradually increased, so that by the time she returned to her home in Florida, she had an almost normal range of motion.

In August 1946, the patient again fell upon her right shoulder. Because of the pain and limitation of abduction, she feared a recurrence of the dislocation and immediately came to New York; but a roentgenogram disclosed a fracture of the greater tuberosity without any displacement. The upper end of the humerus occupied its normal position in the glenoid fossa, and the calcification previously noted had entirely disappeared. The patient was treated by means of a sling, and made a completely uneventful recovery with normal range of motion.

Because of the extremely gentle manipulation employed, the possibility of danger either to nerves or blood vessels is minimal, and injury to them has not been encountered. In all probability, the nerve injuries which are attributed to the method of reduction are coincident with the dislocation. These occur in about one of every seven cases of so-called simple dislocation. In view of the legal implications which may be involved, no dislocation of the shoulder should be reduced until a preliminary and careful investigation for nerve involvement has been made.

Not even an apparently simple dislocation of the shoulder should be treated without roentgenographic examination. Contrary to the opinion of some authorities, fracture of the greater tuberosity occurs in over 10 per cent. of all the cases. While this is not usually of great significance, such a fracture fragment may be interposed between the glenoid fossa and the humeral head and so defeat the most skillful and conscientious efforts at reduction. Visualization of a fractured glenoid rim may forewarn the surgeon against too optimistic a prognosis. Above all, the roentgenogram is of value in the diagnosis of fracture-dislocation. In the presence of extensive hemorrhage, particularly if the patient is seen after the lapse of several days, the clinical diagnosis of fracture-dislocation may present the utmost difficulty.

Because of the impossibility of controlling the small capital fragment, the Kocher manipulation is not only foredoomed to failure, but may be fraught with consequences of a more serious nature. It is in such instances that methods other than the classical have been successfully instituted. This is illustrated in the following cases:

CASE 4. R. M., aged twenty-seven, was admitted to the hospital October 30, 1937, shortly after he had fallen down a flight of stairs, landing on the outstretched left hand, with the elbow held in extension. He complained of severe pain in the left shoulder, radiating down to the posterior aspect of the elbow. In addition, he noted a sensation of numbness in the left hand.

The patient presented the typical clinical appearance of a subcoracoid dislocation of the left shoulder. There was a well-defined ulnar-nerve lesion with definite signs of motor weakness.

The roentgenogram (Fig. 5-A) revealed an oblique fracture of the upper end of the humeral shaft with subcoracoid dislocation of the capital fragment.

Under local anaesthesia and by the method described here, reduction was accomplished without difficulty. The patient's arm was immobilized in a Velpeau bandage. A postreduction roentgenogram (Fig. 5-B) disclosed reduction of the dislocation with excellent reposition of the fractured fragments. Within a week after the reduction, return of some sensation in the ulnar-nerve distribution was noted; after about two weeks, sensation was almost normal, except for some dysaesthesia. This ultimately disappeared, with complete restoration of motion in the shoulder and return of motor power in the muscles supplied by the ulnar nerve.

CASE 5. J. M., aged forty-six, was first seen on January 2, 1947, several days after he had fallen and injured his right shoulder. On the following day, a roentgenogram revealed a fracture-dislocation of the right shoulder.

Examination disclosed the characteristic clinical picture of subacromial dislocation. The roentgenograms

revealed a comminuted fracture of the surgical neck of the humerus with a subcoracoid dislocation of mild degree (Fig. 6-A).

Because of the fracture, the possibility of using the Kocher manoeuvre for reduction of the dislocation could not be considered, and it was determined to attempt reduction by the method of overhead traction-pulsion. Under gas, oxygen, and ether anaesthesia, the arm was gently brought into the complete overhead position. The dislocation was promptly reduced with hardly any force, and the arm was brought to the side (Fig. 6-B). A hanging plaster-of-Paris cast was then applied to the arm and forearm. As soon as the patient had recovered from the anaesthesia, he was permitted to be up and about. He was discharged from the hospital on January 5, 1947.

The hanging plaster was left on for a little over five weeks, after which time physical therapy and active motions were begun. Function was gradually restored, so that by the end of April the patient was able to return to his usual duties as a police officer.

Case 6. R. K., aged sixty-four, was seen on July 7, 1947, shortly after she had slipped and fallen on her

Fig. 6-A

Fig. 6-B

Fig. 6-A: Case 5, J. M. Comminuted fracture of the surgical neck with subcoracoid dislocation on the right side.
Fig. 6-B: Immediately after reduction.

Fig. 7-A

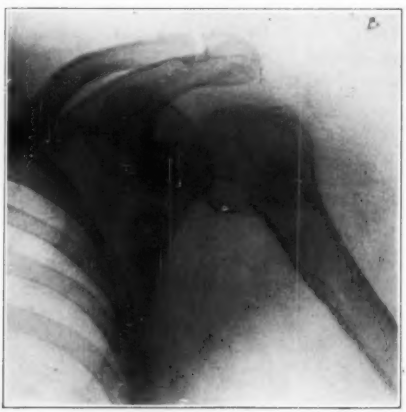

Fig. 7-B

Fig. 7-A: Case 6, R. K. Fracture-dislocation of left shoulder before reduction.
Fig. 7-B: After reduction.

outstretched left arm. The patient presented the typical appearance of a dislocation of the shoulder. There were no signs of any nerve involvement. The roentgenogram (Fig. 7-A) disclosed a subcoracoid dislocation of the head, with a longitudinal fracture of the greater tuberosity and a transverse fracture of the surgical neck of the humerus.

Because of the patient's extreme nervousness, the use of gas-oxygen anaesthesia was deemed necessary. As soon as primary analgesia had been obtained, the arm was gently manipulated into the overhead position and reduction was accomplished with almost no force (Fig. 7-B). The arm was immobilized in a Velpeau bandage, but slight active flexion and extension were begun within a few days. At the end of three weeks, active graded exercises were instituted.

FIG. 8

While still allowing limited motion, the "check rein" prevents excessive abduction of the shoulder after reduction.

In the treatment of simple dislocations, early motion is encouraged. Immobilization by means of a restrictive bandage is purposely avoided. The patient is provided with a sling and is urged to use the arm in all directions, except in abduction and in external rotation. By applying a "figure-of-eight" adhesive strap around the affected arm and the trunk, a "check" ligament is created, and the degree of abduction can be readily controlled (Fig. 8). As healing of the torn structure progresses, a greater degree of abduction may be permitted by gradually increasing the length of this "check" ligament. In this manner, function can be instituted from the very beginning, and the limiting effect of periarthritis can be minimized. Where the dislocation is complicated by a fracture, the beginning of motion must be deferred until consolidation has taken place. This may be accomplished by a Velpeau bandage, a hanging plaster, an abduction splint, or by traction in the recumbent position, as the exigencies of the case indicate.

CONCLUSIONS

During the past ten years, many types of shoulder dislocations, both with and without fracture, have been studied. In all, the treatment here described has been employed. The method has been found easy in its application and gratifying in its results. In no instance could any bone, vascular, or nerve lesion, be attributed to its use. It is founded upon a proper regard for the anatomy of the part; and, in consequence, requires exhibition of only a minimum of "brute force" to achieve satisfactory reduction. In most instances, it can be carried out without the necessity of narcosis. This holds true even for old and infirm patients, provided their confidence has been obtained and is not abused. Because of this, it may be used as an office or Out-Patient Department procedure.

(In an editorial on "Recurrent Dislocation of the Shoulder" in the British Volume of *The Journal of Bone and Joint Surgery* [**30-B:** 6–8, Feb. 1948], particular stress has been laid upon the necessity of preventing external rotation by immobilizing the shoulder in internal rotation for a period of at least four weeks. This seems to be in conformity with a very rational concept of shoulder dislocations, and should be employed in the post-reduction phase of the treatment.)

REFERENCES

1. CAMPBELL, W. C.: Operative Orthopedics. St. Louis, C. V. Mosby Co., 1939.
2. CODMAN, E. A.: The Shoulder. Rupture of the Supraspinatus Tendon and Other Lesions in or about the Subacromial Bursa. Privately printed, Boston, 1934.
3. CUBBINS, W. R.; CALLAHAN, J. J.; and SCUDERI, C. S.: The Reduction of Old or Irreducible Dislocations of Shoulder Joint. Surg., Gynec., and Obstet., **58:** 129–135, 1934.

4. KOCHER, THEODOR: Eine neue Reductionsmethode für Schulterverrenkung. Berliner Klin. Wchnschr., 7: 101–105, 1870.
5. MILCH, HENRY: Treatment of Dislocation of the Shoulder. Surgery, 3: 732–740, 1938.
6. WATSON-JONES, R.: Robert Jones' Traction. *In* Fractures and Joint Injuries, Ed. 3, Vol. 2, pp. 460–461. Baltimore, Williams and Wilkins Co., 1943.

DISCUSSION

TRAUMATIC DISLOCATION OF THE HUMERUS

(Continued from page 172)

DR. JOHN J. FAHEY, CHICAGO, ILLINOIS: We are indebted to Dr. Nicola and to Dr. Wilson and Dr. McKeever for these important contributions to the subject of shoulder dislocations. As previously reported by Dr. Nicola, Dr. DiCosola and I found that the most constant lesion of experimental dislocation seen at autopsy is a tearing of the capsule from the humeral neck, a portion of the subscapularis tendon sometimes being included. We were not able to produce an impacting force, while the extremity was in abduction and external rotation, which we thought was responsible for the shearing of the labrum from the glenoid. Abduction and external rotation will produce tears of the labrum from the glenoid or capsular tears from the labrum in approximately 25 per cent. of shoulders dislocated at autopsy. This same manoeuvre will frequently tear the capsule from the humeral neck on one side and will result in some type of lesion of the labrum on the opposite shoulder.

It is not easy to state that the mechanism causing labrum tears in young athletes is different from that in older individuals. Younger individuals quickly resume activity, and Dr. Nicola's apparatus for preventing abduction and external rotation seems promising in reducing the incidence of recurrence.

Immobilization for a period of eight weeks in older patients may result in some type of shoulder disability which outweighs the chance of recurrence.

Dr. Wilson and Dr. McKeever have focused our attention on a very rare type of shoulder lesion. Lack of experience with this dislocation does not permit me to discuss this paper thoroughly. If we follow these suggestions for early recognition of the cases, our information on this type of dislocation, which has been so clearly demonstrated, should rapidly increase.

DR. GEORGE E. BENNETT, BALTIMORE, MARYLAND: I have observed two cases of recurrent posterior dislocation of the shoulder in which reduction could be easily accomplished, but in which the head of the bone would immediately become redislocated posteriorly. In both cases, it was found at exploration that the biceps tendon had been partially torn from its sheath and was acting as a bowstring, preventing the shoulder from remaining in position.

DR. TOUFICK NICOLA (closing): Perhaps the eight-week period that I mentioned would be changed in older patients. There is no question in my mind that, if the shoulders in young patients are not immobilized, 100 per cent. recurrence will follow the acute dislocation, as happened in our series.

The dressing used after reduction allows flexion and extension of the elbow, pronation, supination, and full use of the hand; and yet it does not allow too much atrophy, as would happen if you put it close to the chest.

DR. JOHN C. WILSON (closing): It is believed that the shoulder joint is not stable in external rotation, as suggested by Dr. Giannestras. Complete internal rotation of the arm, with the forearm behind the back, was the only position which we found to be stable after open or closed reduction of a posterior dislocation of the shoulder. This position is not a comfortable one for the patient.

Dr. Bennett's suggestion of a displaced biceps tendon is most interesting. It is easy to understand how such a displacement of the biceps tendon could prevent stable reduction of a posterior dislocation of the shoulder. It happened not to be present in the cases under our observation in which the shoulders were opened.

Transfixion of the humeral head by means of wires placed through the spine of the scapula has proved to be a satisfactory method of maintaining the reduced humeral head in the glenoid. The procedure is simple, the patient is comfortable, and no mechanical difficulties are offered.

There are two suggestions to remember in this discussion: one is the lateral x-ray in suspected dislocation of the shoulder, and the other is the simplicity of transfixion to maintain the reduction.

METASTATIC ADENOCARCINOMA OF THE TALUS FROM THE RECTOSIGMOID REGION

Report of a Case

BY E. W. JOHNSON, JR., M.D., ROCHESTER, MINNESOTA
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AND JOSEPH M. JANES, M.D., ROCHESTER, MINNESOTA
Section on Orthopedic Surgery, Mayo Clinic

Since this presentation is made primarily to report a case of distant bone metastasis from carcinoma of the rectum, a comprehensive review of the literature on this subject is not contemplated; however, some background material is needed. The incidence of metastasis to the skeleton has been variously estimated as from 0.5 to 11.1 per cent. of all cases of rectal carcinoma. Mayo and Schlicke, in their review of 334 cases of carcinoma of the rectum and colon, found that regional or distant metastasis had occurred in 60.5 per cent. of the cases, but that metastasis to bone had occurred in only 1.2 per cent. In an analysis of 366 cases of carcinoma of the lower part of the bowel, Bacon noted metastasis to the skeleton in fifteen cases (4.1 per cent.); in six of these the vertebrae were involved, in two the femur, in two the skull, in two the ribs, in two the shoulder girdle, and in one

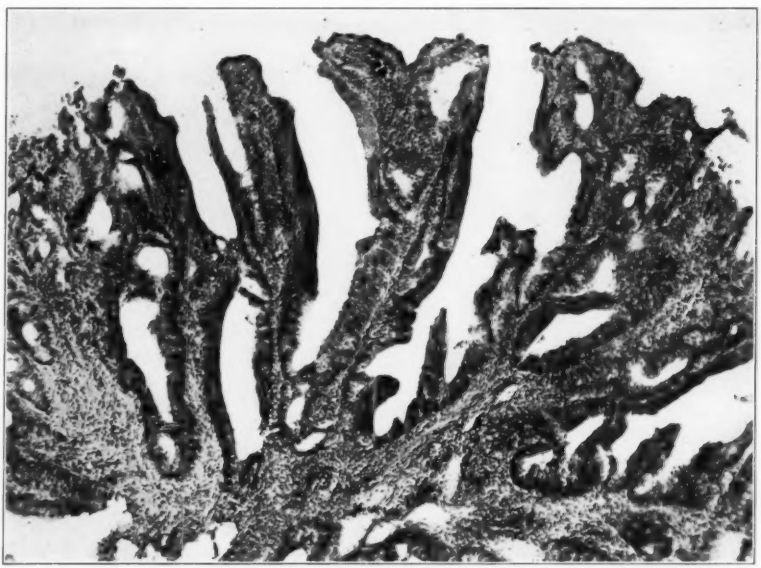

Fig. 1

Photomicrograph (× 55) of tissue removed at operation in March 1942, showing adenocarcinoma, Grade 2 (Broders' classification), of the rectum (hematoxylin and eosin stain).

the sternum. All the lesions were osteolytic in character. Turner and Jaffe found, at necropsy, skeletal metastasis in 11.1 per cent. of 1,303 cases of neoplasm of the large bowel. Ghormley and Valls found the incidence of metastasis to bone "from 0.2 to 0.5 per cent. of all cases of carcinoma of the gastro-intestinal tract, with the highest incidence of such metastasis in cases of carcinoma of the rectum".

The anatomical pathways involved in the spread of rectal carcinoma are the classical ones,—namely (1) direct extension, (2) the lymph vessels, (3) the blood stream, and (4) transplantation through the peritoneal cavity. Grinnell, in a comprehensive study of seventy-five cases, ably discussed the latter two methods of spread and concluded that distal spread of malignant tumors of the rectum is exceedingly rare and that proximal spread is the rule. Mechling suggested that tumor emboli, entering the thoracic duct from the blood stream, can result in bizarre metastatic lesions. Batson has shown, by his injection experiments in both cadavera and monkeys, that the vertebral veins must be considered as a partial, if not complete, explanation of the manner and route of tumor spread.

In spite of all that has been written on metastatic growth of tumors, not one of the theories explains the scarcity of metastatic lesions below the knees and elbows. It might be conjectured that the more proximal metastatic lesions cause death before evidence of metastasis to an extremity is apparent. With the fact as a basis that metastases to the testes and scrotum are rare and that the temperature of the scrotum is 6 degrees Fahrenheit less than that of the body cavity, it has been postulated that secondary tumor growth below the knees and the elbows is rare because of the decreased temperature of the extremities. Whatever the reason, reports of metastasis to an extremity in cases of carcinoma of the rectum are exceedingly rare. Weston reviewed the literature and found only six cases. He stated that, in 1870, Curling had reported a case of rectal carcinoma with metastasis to the upper part of the radius; and Pitts, in 1891, Aufses, in 1930, Geschickter and Copeland, and Hayden, in 1936, had all reported cases of metastasis to the humerus, in two of which spontaneous fractures were the first symptoms. The sixth case discovered by Weston was also of humeral metastasis, reported by Brown and Warren in 1938.

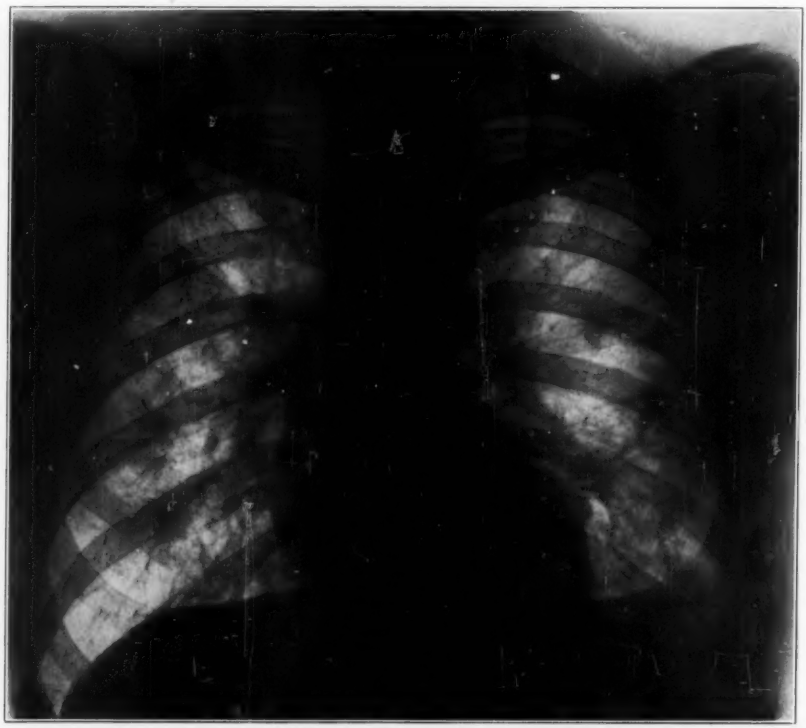

FIG. 2

September 1947. Numerous metastatic lesions in the chest, not unlike inflammatory lesions.

CASE REPORT

A well-developed, well-nourished white man, thirty-seven years old, came to the Mayo Clinic in March 1942, because he had noted red blood on the surface of his stools for the preceding seven weeks. The patient had no other complaints, and was having only slight occasional distress from a duodenal ulcer for which he had received treatment since 1934. He had 13.3 grams of hemoglobin per 100 cubic centimeters of blood, and the red-blood-cell count was 4,810,000. The sedimentation rate was 18 millimeters per hour (Westergren method). Urinalysis and the Kahn test for syphilis gave negative results. Roentgenographic examination of the chest revealed nothing of significance, and roentgenoscopic study of the stomach and duodenum after the ingestion of barium was interpreted as indeterminate. Proctoscopic examination was carried out to a distance of 24 centimeters; 20 centimeters above the anus a movable lesion was noted, involving the posterior wall. Grossly this was diagnosed as a carcinoma. Material taken for biopsy at this time was diagnosed in the Pathology Laboratory as adenocarcinoma, Grade 2, of the rectum.

On March 28, an anterior resection of 9.5 centimeters of the lower part of the sigmoid colon and rectum was performed and an ulcerating adenocarcinoma, Grade 2, measuring 4 by 3 by 1 centimeters was found (Fig. 1). The growth had penetrated the bowel wall, involving the serosa and also the adjacent lymph nodes. The surgeon could feel no metastatic lesions in the liver. The postoperative course was uneventful except for one period of transient jaundice, and the patient left the Hospital on the thirty-fifth postoperative day.

The patient returned to the Clinic at intervals of six months after this operation, and a proctoscopic examination was performed each time. In December 1946, the distal 26 centimeters of the bowel was pronounced clear. However, in January 1947, the patient returned with a vague history of increased gurgling and activity in the upper middle portion of the abdomen of three months' duration, and of persistent postprandial vomiting and inability, for the past week, to pass a stool without the aid of an enema. He had lost a moderate amount of weight. He was admitted to the Hospital and a conservative regimen, consisting of the administration of intravenous fluids, a soft diet, and sedation, was instituted. He seemed to progress fairly well, but on the tenth day in the Hospital symptoms of obstruction became prominent and an emergency laparotomy was done. At operation, hard nodes were felt around the head of the pancreas and in the periaortic region; and at the ligament of Treitz there was a mass which was obstructing the intestine. A posterior gastro-enterostomy was done. Unfortunately no specimen was removed for biopsy, but the surgeon considered the lesion metastatic.

Routine roentgenograms of the chest, in January 1947, showed an area of infiltration at the level of the second anterior interspace, which was thought to be minimal tuberculosis. A series of sputum examinations were negative for acid-fast bacilli at this time.

FIG. 3-A FIG. 3-B

September 1947. Destructive process in the posterior tip of the left talus, suggestive of destructive arthritis with effusion.

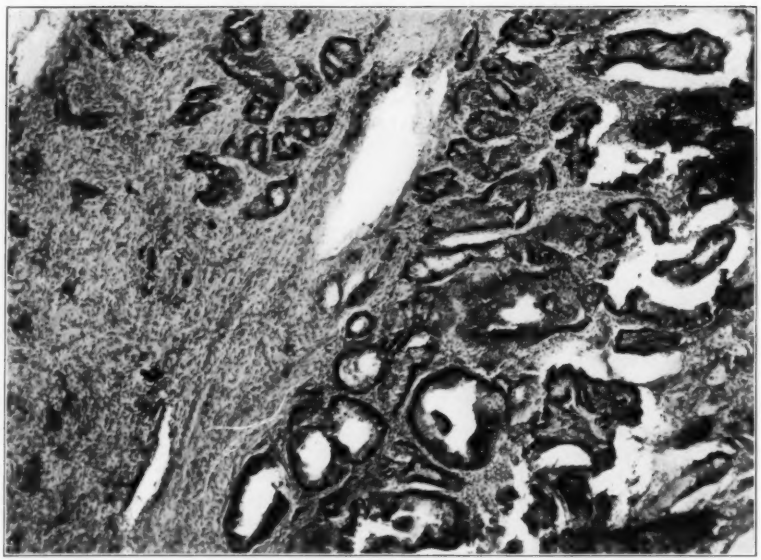

FIG. 4

Photomicrograph (× 55) of specimen removed from the left talus shows the invasion of the bone by adenocarcinoma, Grade 2, of the rectum (hematoxylin and eosin stain).

In July, the patient returned because of intermittent pain and swelling of the left leg and ankle of about four months' duration. He had had anorexia and had been losing weight gradually since January. Roentgenograms of the left ankle failed to reveal any lesion, but those of the chest showed an increase in size and number of the lesions first noted in January. Repeated examinations of sputum were again negative for acid-fast bacilli, although the opinion of the various consultants favored a diagnosis of metastatic malignant lesions rather than tuberculosis. Biopsy of material from the ankle was considered, but in view of the fact that some hemoptysis had occurred in the preceding month, biopsy was deferred, and a course of five roentgen treatments was given to the abdomen and left ankle with some relief of pain.

On his return in September, the patient complained of continued pain and swelling in his left ankle, which had become severe enough to prevent his bearing weight on the extremity. He also complained of easy fatigability, lack of appetite, and gradual loss of weight. The lesions in the thorax were still progressing (Fig. 2) and his cough and hemoptysis had become more severe. Roentgenograms of the left ankle revealed a destructive process of the posterior superior aspect of the talus, which was strongly suggestive of a destructive arthritis with effusion (Figs. 3-A and 3-B). The concentration of alkaline phosphatase was 9.7 and that of acid phosphatase was 2.3 King-Armstrong units per 100 cubic centimeters of serum. Since it was felt that a biopsy examination of the talus would greatly clarify the interpretation of the condition in the thorax, even though repeated sputum examinations were negative for malignant cells and acid-fast bacilli, a specimen was removed from the talus. The pathologist reported adenocarcinoma, Grade 2, with frank rectal tissue present (Fig. 4). The patient was given another series of roentgen treatments to the left ankle. A letter from his wife, in December 1947, indicated that the patient was in his last illness. He died on April 13, 1948.

REFERENCES

BACON, H. E.: Unusual Sites of Metastasis from Carcinoma of the Rectum and Sigmoid Colon. Pennsylvania Med. J., **43:** 1573–1577, 1940.

BATSON, O. V.: The Function of the Vertebral Veins and Their Role in the Spread of Metastases. Ann. Surg., **112:** 138–149, 1940.

GESCHICKTER, C. F., and COPELAND, M. M.: Tumors of Bone, Ed. 2. New York, Am. J. Cancer, 1936.

GHORMLEY, R. K., and VALLS, J. E.: Metastasis to Bone from Carcinoma of the Gastro-Intestinal Tract. J. Bone and Joint Surg., **21:** 74–78, Jan. 1939.

GRINNELL, R. S.: The Lymphatic and Venous Spread of Carcinoma of the Rectum. Ann. Surg., **116:** 200–216, 1942.

(*Continued on page 202*)

BILATERAL OSTEOCHONDRITIS DISSECANS OF THE PATELLA

BY SAMUEL KLEINBERG, M.D., NEW YORK, N. Y.

Osteochondritis dissecans of one joint is a fairly common lesion. It is most frequently found in the knee, but occurs also in other joints, especially the elbow, ankle, and hip. A bilateral lesion of the patella, although known, is rare. The case to be reported is the only one seen by the author. There was no history of trauma, and the anatomy of the joints, clinically, roentgenographically, and at operation, revealed no abnormality or anomaly to which the pathological findings could be attributed.

M.H., sixteen years old, was seen on February 1, 1945, because of swelling and occasional pain in the *left* knee. The pain had occurred intermittently for several weeks; the swelling had appeared ten months previously, without any known antecedent injury or illness. This patient was an active boy, indulging in many sports.

The examination revealed moderate enlargement of the left knee with some excess of synovial fluid. There was distinct thickening of the synovial tissue in the suprapatellar area, but no local heat. Motions of the knee were free and there was no abnormal mobility. There was atrophy of the left thigh of one and seven-eighths inches. There was no tenderness to pressure over the patella, the articular surfaces of the femoral condyles, or the menisci. Lateral roentgenograms (Fig. 1) showed an excavation of the middle two fourths of the articular surface of the patella. No loose body was seen, but the diagnosis of osteochondritis dissecans was fairly evident.

On February 13, the knee was exposed through a medial parapatellar incision. A large irregular chondral body lay on the anterior aspect of the articular surface of the femur, directly behind the patella and connected by a slender pedicle to the medial portion of the posterior surface of that bone. Here the articulating cartilage was absent over an area of about one square inch, having been replaced by friable, soft, connective tissue. The replacement tissue was excised, together with the pedicle and loose body. The thickened and congested synovial membrane in the suprapatellar pouch was also excised. The excavated area was curetted.

The pathologist's diagnosis was chondritis (osteochondritis) dissecans of the patella.

In June 1945, while the left knee was still under treatment, the patient complained of discomfort in the *right* knee. The clinical findings and a roentgenographic study (Fig. 2), made on June 20, were negative. A check-up examination on September 19 was also negative, but the boy stated that after sitting for a long while and getting up he had had momentary discomfort on the medial side of the knee. The following night he was awakened by pain and found that his knee had locked. Examination a few hours later revealed a palpable loose body in the suprapatellar area, medial to the patella. The patient stated that he had felt the loose body several times previously, but had not mentioned it.

FIG. 1

FIG. 2

Fig. 1: Lateral view of left knee shows an excavation of the middle two fourths of the articular surface of the patella.

Fig. 2: In lateral view, the right knee is apparently negative and was diagnosed as such originally, but in retrospect there appears to be a slight indentation on the middle of the articular surface of the patella.

On September 24, a large, loose, seemingly osteochondral body was removed from the quadriceps pouch. On the lateral portion of the articular surface of the patella was found a crater, from which the loose body had evidently originated. There was no other evidence of chondromalacia in the patella or the femur. The edges of the crater were beveled and its base was made smooth by curettage.

The pathologist's report stated that sections showed the loose body to be essentially cartilaginous. The diagnosis was osteochondritis (chondritis) dissecans.

The patient was discharged as well on April 19, 1946.

A MODIFIED PLASTER-OF-PARIS SPICA JACKET

BY BOYAN HADJISTAMOFF, M.D., SOFIA, BULGARIA

From the Surgical Clinic, Sofia University, Sofia

The plaster-of-Paris spica jacket developed by the author is constructed of several plaster slabs. The first encircles the iliac crests and the second surrounds the thorax near the axillae, each slab being reinforced by several encircling turns. Two vertical slabs go over the shoulders; at each place of crossing they are fastened to the upper horizontal slab by means of two gauze strips, previously inserted under the horizontal slab. The vertical slabs are also attached to the horizontal slabs by means of several encircling turns. Then the axilla is molded with a small slab (40 centimeters in size). A plaster jacket provided with openings is thus formed, which supports the upper extremity. The sixth and last slab is placed along the length of the entire upper extremity. The fifth and sixth slabs are supported by encircling turns over the shoulder and around the limb. The plaster "slab" spica jacket is completed by the placing of the supporting stick between the anterior superior spine and the forearm, near the wrist joint (Figs. 1 and 2).

FIG. 1

FIG. 2

"Slab" jacket applied to patient who had been operated upon for habitual dislocation of the shoulder joint.

The technique described makes the plaster-of-Paris spica jacket light and cheap. No more than twelve plaster bandages, 8 to 10 centimeters wide, and a comparatively small quantity of cotton, are used. With the aid of trained assistants and with previously prepared plaster slabs (rolled like a bandage), the plaster-of-Paris spica jacket can be applied in ten or fifteen minutes. The body is well ventilated and can be partially cleaned. Breathing is unrestricted.

FIBROUS DYSPLASIA

Report of a Case

BY PHILIP T. SCHLESINGER, M.D., GLENS FALLS, NEW YORK, AND SIDNEY KEATS, M.D., AND ANDREW C. RUOFF, III, M.D., ORANGE, NEW JERSEY

From the New Jersey Orthopaedic Hospital, Orange

The purpose of this paper is to record a case of fibrous dysplasia of bone, presenting the unusual complication of massive hemorrhage with absorption of a large section of the tibia.

Jaffe described a case of fibrous dysplasia in which a similar complication had occurred in a rib. Although vascular dilatation and capillary hemorrhage are frequently noted in fibrodysplastic lesions, Jaffe's case is the only one known to have been reported in which massive hemorrhage occurred.

A preoperative diagnosis of sarcoma was made in this case and in Jaffe's case, because of the rapid development of the lesions. In each, extensive pathological study of the lesions which had been removed *in toto* failed to reveal any evidence of malignancy, the changes being ascribed by the pathologist to massive hemorrhage. In the case described here, this complication might have been suspected because, in two previous operations on the patient's femur and tibia, bone bleeding was encountered which was extremely difficult to control.

CASE REPORT

C. S., a white boy, was first seen on May 18, 1937, at the age of five years, with a fracture of the right femur which had occurred two years before and which had failed to unite. The roentgenograms showed generalized osteoporosis and distention of the entire right shaft, characteristic of fibrous dysplasia, and an ununited transverse fracture at the junction of the upper and middle thirds. Roentgenographic changes of a similar nature were seen in the upper third of the shaft of the left femur; and changes characteristic of an early stage were present in the right tibia (Fig. 1) as well as in the left tibia.

On June 4, 1937, an open reduction of the fracture of the right femur was performed. It was noted that the bone was unusually vascular. Fibrous tissue was removed from the site of fracture, and bone grafts were placed. Lateral bowing was corrected manually and a hip spica was applied. On microscopic examination of the specimen, fibrous tissue containing numerous small blood vessels and occasional bone trabeculae was seen, and the diagnosis of fibrous dysplasia was made. On September 22, 1937, there was bony union clinically and by roentgenogram. The spica was removed. Refracture occurred thirty-eight days later, when the patient fell at home. He was again immobilized in a spica for three and one-half months, at the end of which time roentgenograms showed a moderate amount of callus. One month later, on March 13, 1938, he again fractured this bone while lying in bed. At a second operation, March 1938, the cortex was found to be quite thin and broken through. The medullary cavity was filled with fibrous tissue which was extremely vascular and bled profusely wherever disturbed. This was thoroughly curetted for some distance and packed with iliac grafts. After four and one-half months, the fracture was clinically solid, although the roentgenograms showed little callus.

The patient returned January 3, 1939, complaining of pain in the region of the right tibia (Fig. 2); he had fallen while walking with crutches, three days before. On physical examination there was found to be tenderness over the tibia anteriorly, at the junction of the upper and middle thirds. Roentgenographically, there was no evidence of fracture, but considerably more of the bone was involved in the dysplastic process and there was localized rarefaction in the tender area.

On his return, March 27, the mother stated that bowing of the right leg had been noted two weeks before. The roentgenogram taken at that time showed an incomplete fracture line at the junction of the upper and middle thirds. There was lateral and anterior bowing. The entire shaft showed involvement in the pathological process. A hip spica was applied. After seven months, the patient became ambulatory, with a brace supporting his right leg.

Between January 3, 1939, and October 3, 1944, the patient suffered successive pathological fractures of the right ulna, both bones of the right forearm, right femur, right humerus at the lower third, right humerus

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Right leg, May 18, 1937. There is involvement of the middle two quarters of the tibia with slight distention and some areas of rarefaction.

Fig. 2: Right leg, January 3, 1939. Showing involvement of upper two thirds of the shaft of the tibia with distention and thinning of the cortex and rarefaction. Some irregular sclerosis can be seen in the upper portion. Slight anterior bowing is present in the lateral view.

Fig. 3: Right leg, July 23, 1942. Showing healed pathological fracture with the plate and screws *in situ*.

at the middle third, and two fractures of the left femur. Roentgenograms of these bones showed extensive changes characteristic of fibrous dysplasia.

On April 26, 1942, while not wearing his brace, the patient fell and fractured his right tibia. This fracture was plated, and a toe-to-groin cast applied. Three months later, the fracture of the tibia appeared solidly united, both clinically and by roentgenogram (Fig. 3).

The case was reviewed at this point (Fig. 4). Because of his many fractures and the extent of the disease, biopsy was performed on October 27, 1944, to obtain material for further pathological study. On reflection of the periosteum, very active bone bleeding commenced which was controlled by bone wax. A cube of bone, 1.3 centimeters square, was removed at the junction of the upper and middle thirds of the right tibia. Massive hemorrhage was encountered, which was controlled only by prolonged direct pressure after implantation of a piece of muscle. The wound healed well with no evidence of hematoma. Microscopic examination of the biopsy tissue showed evidence that cartilage was replacing much of the osseous tissue. Between the bone trabeculae were many large areas of fibrous tissue which appeared mature histologically, and the diagnosis of fibrous dysplasia was again made.

The patient next returned on October 15, 1946, with a history of spontaneous swelling over the right shin of three weeks' duration. This area had become quite prominent and very tender. He had noticed that the bone seemed to drop away from the skin at this point. He complained of weakness and anorexia. Examination of the right leg showed a prominent diffuse swelling over the anterior aspect of the middle third of the right tibia. There was no redness, but increased heat as well as a considerable amount of diffuse tenderness. The mass was fairly firm but not hard at any point, and a sensation of crackling could be felt. There was definitely abnormal mobility. No discoloration was present. The patient complained of much pain on motion of the leg. Roentgenographically, in the mid-portion of the tibia, there appeared to be complete dissolution of the osseous elements for a distance of 7 centimeters, the normal bony outline being replaced by three large cystic areas. There was extreme atrophy of the fibula, only a string-like remnant remaining (Fig. 5). The proximal third of the tibia showed an irregular elevation of the periosteum. The bone appeared as regularly mottled osseous material, with no trabeculation and no discernible cortex or medulla. It was thought

that sarcomatous degeneration had taken place and, on October 18, a supracondylar amputation of the right thigh was performed. Despite considerable hemorrhage from the end of the femur and soft tissues, healing was uneventful.

Microscopic examination of tissue taken from several parts of the amputated specimen failed to reveal evidence of malignancy. The microscopic picture revealed not only the characteristic findings of fibrous dysplasia—large areas of mature fibrous tissue interspersed with bone trabeculae, islands of calcified cartilage, and endothelial-lined spaces—but also evidence of fairly recent massive hemorrhage and degeneration of tissue.

The following excerpts are from the description of the gross specimen of the tibia (Fig. 6) by Henry L. Jaffe:

"The tibia was exposed by dissecting the soft parts away from it. In the middle third of the tibia, on the medial side, a metal plate was found, attached to the bone by four screws, this plate having been inserted at the time of treatment of the pathologic fracture. The plate was removed in the course of the dissection. There was complete union of the fracture at the site of the plate. The fibula was thin and rather tortuous, and was separated away from the tibia. The muscles of the leg were extremely atrophic. The vessels showed nothing remarkable. Specifically, they were examined for bulbous expansions as evidence of neurofibromatosis, but there was no sign of this anywhere.

"The tibia was cut in the sagittal plane. The cut surface showed that the expanded flail area was the

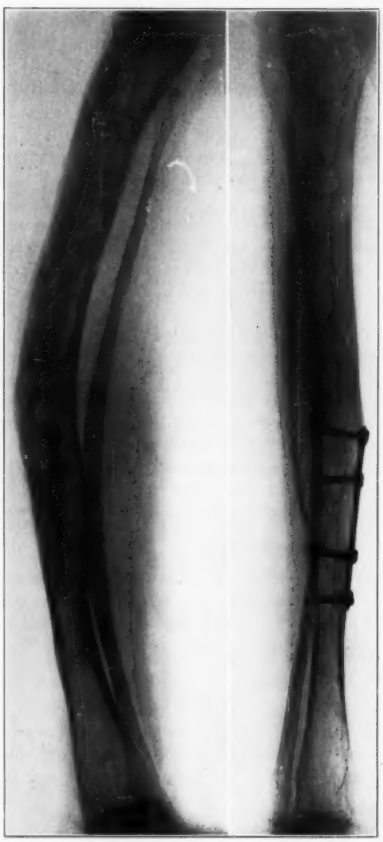

FIG. 4

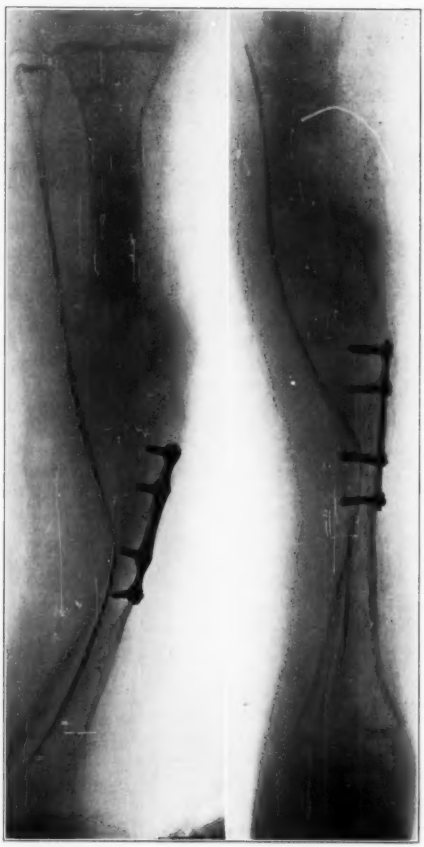

FIG. 5

Fig. 4: Right leg, October 28, 1944. Showing the characteristic stippling of the late stage.

Fig. 5: Right leg, October 15, 1946. A large shadow of soft-tissue density can be seen in the mid-portion of the leg. The middle quarter of the tibia can be faintly seen in this mass. The upper two thirds of the fibula has been reduced to almost string-like size, with a tortuous contour.

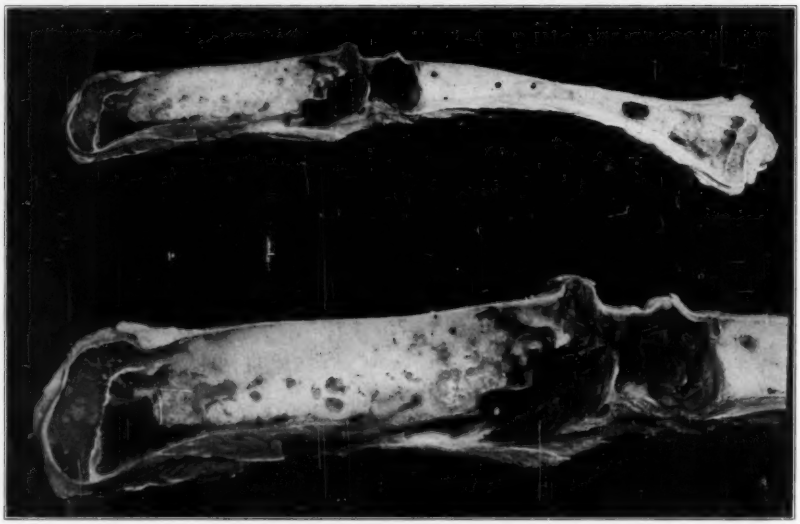

FIG. 6

Sagittal section of the right tibia. Cyst formation and hemorrhage are seen in the expanded flail area. No bone can be seen in the interior in this region. The remainder of the shaft consists of pathological tissue, showing compact trabeculae, fibro-osseous tissue, and islands of hyaline cartilage.

site of cystification and hemorrhage and that in this area all bone substance was lacking in the interior, the continuity of the upper and lower fragments of the tibia being maintained by the periosteum and, in places, by a shell of subperiosteal new bone. The cystified area of dehiscence in the tibia measured about 7 centimeters in length, and its lower end began at the level of the uppermost screw, which held the plate against the medial surface of the tibia.

"The cut surface also shows that the interior of the tibia, above the dehiscence, is completely obliterated except for about 1.5 centimeters below the upper epiphysial plate. The tissue filling the marrow cavity is quite osseous and is composed apparently of closely compacted trabeculae of new bone. Within the substance of this new bone there are some small islands of hyaline cartilage and a larger focus of hyaline cartilage is present at the upper margin of the obliterating osseous tissue and considerably more cartilage at its lower extent. The latter cartilage forms the upper border of the hemorrhagic cystic cavity. Below the dehiscence, the marrow cavity is obliterated for 5 centimeters by compacted trabeculae of osseous tissue whose fibro-osseous nature is more evident in the immediate vicinity of the cyst. The lower half of the tibia also shows, beyond the large obliterating tissue mass, a few smaller scattered areas of osseous tissue, the lowest of which reaches to the lower plate.

"In the sagittal cut surface, the lower epiphysis shows atrophy of the spongiosa but no evidences of fibrous dysplasia. However, the upper epiphysis shows a few scattered islands of fibro-osseous tissue in its central region. The epiphysial cartilage plates of the tibia in the plane of the section are not particularly remarkable, though, abutting on the metaphysial side of the upper plate, there is a small island of cartilage. The cortex of the tibia is thin everywhere, and whatever undiseased spongy bone is present is extremely atrophic."

Laboratory Findings

Except for a somewhat elevated phosphatase level on one occasion, the laboratory tests have been within normal limits. These have included blood counts; bleeding, clotting and prothrombin time; blood calcium, phosphorus, cholesterol, chloride, and erythrocyte sedimentation rate. Urinalysis and blood Wassermann reaction were negative.

It should be mentioned that this patient has shown none of the extraskeletal manifestations of Albright's disease. The onset of puberty was normal. No pigment spots have been found in the skin.

Jaffe, in 1946, discussed a case with development of symptoms similar to those in this case. The patient presented a tumor, the size of a football, in a fibrodysplastic rib. The

rib was resected by Leo Mayer, and a diagnosis was made of sarcomatous degeneration of a fibrodysplastic lesion. The pathological findings were similar to the findings in this case,—that is, there was no evidence of malignancy; the swelling was due to massive hemorrhage.

It would seem, on the basis of these two cases, that the clinical picture of fibrous dysplasia should be broadened to include the complication described here. This complication may be suspected in a patient with fibrous dysplasia, who presents a rapidly expanding bone tumor.

REFERENCES

ALBRIGHT, FULLER; BUTLER, A. M.; HAMPTON, A. O.; and SMITH, PATRICIA: Syndrome Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation and Endocrine Dysfunction, with Precocious Puberty in Females. Report of Five Cases. New England J. Med., **216:** 727–746, 1937.

FALCONER, M. A.; COPE, C. L.; and ROBB-SMITH, A. H. T.: Fibrous Dysplasia of Bone with Endocrine Disorders and Cutaneous Pigmentation (Albright's Disease). Quart. J. Med., **11:** 121–154, 1942.

JAFFE, H. L.: Fibrous Dysplasia of Bone. Bull. New York Acad. Med., **22:** 588–604, 1946.

LICHTENSTEIN, LOUIS, and JAFFE, H. L.: Fibrous Dysplasia of Bone. A Condition Affecting One, Several or Many Bones, the Graver Cases of Which may Present Abnormal Pigmentation of Skin, Premature Sexual Development, Hyperthyroidism or Still Other Extraskeletal Abnormalities. Arch. Pathol., **33:** 777–816, 1942.

A TYPE OF EXTENSION APPARATUS*

BY A. VON PETZ, M.D., GYÖR, HUNGARY

From the Surgical Division of the Holy Trinity Hospital, Györ

The apparatus described here has two advantages: First, it can be easily mounted on any operating table; and, second, its extensor action corresponds accurately to the axis of the involved limb.

Since Mathijsen introduced the plaster-of-Paris bandage in the latter half of the nineteenth century, numerous extension devices have been developed to facilitate the application of plaster immobilization dressings. When examined carefully, it is found that almost all fail to exert a pull in the true axis of the limb, because they do not take into account the anatomy of the locomotor apparatus and the differences caused by age and sex. The only striking exceptions are the large orthopaedic tables of Albee, Compere, and Roger Anderson. It would be well for those who devise extension apparatus to accept the advice given by Hippocrates to his son, Thessalus: "Study geometry and arithmetic, if you would gain a better knowledge of the bones".

As is well known, the femora are not parallel to one another; they, together with the tibiae, form a triangle whose base is the width of the pelvis. The width of the base is further increased by the outward inclination of the femoral neck. In women, the base of the triangle is broader than in men. Since almost all extension devices are attached to the perineal bar, it is obvious that the pull is directed, not in the axis of the femur, but at an angle; and that, if the femur has been fractured, the effect of such a pull is to create a valgus deviation of the distal fragment. True axial extension must, of course, have its

* Translated from the German by Leo Mayer, M.D., New York City.

fixed point so placed as to correspond to the tip of the greater trochanter, which represents the upper continuation of the diaphysis of the femur.

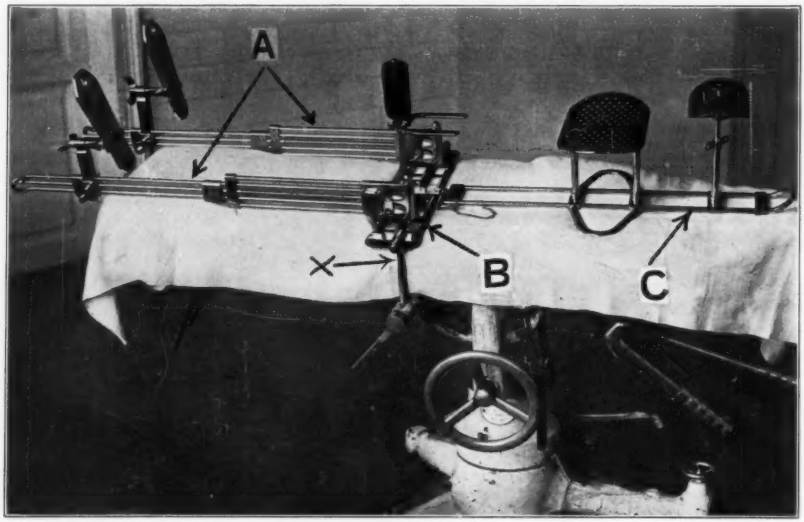

FIG. 1

Photograph of the extension apparatus, mounted on an operating table.
A: Extension bars with adjustable foot plates.
B: The crossbar, which can be adjusted to correspond to the intertrochanteric measurement of the patient. To it is attached a padded perineal bar and a horseshoe-shaped pelvic rest.
C: Adjustable thoracic and head supports.
X: Attachment of the apparatus to the table by means of lateral arms; these fit into the clamps which hold the leg supports employed for the lithotomy position.

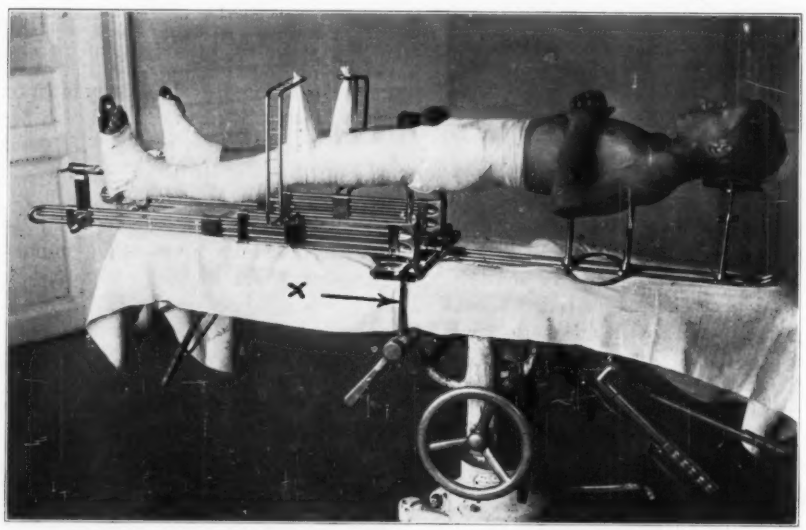

FIG. 2

Shows the method of using the suspension frames to prevent sagging of the limbs during the application of plaster-of-Paris spica.

The apparatus described here meets these anatomical and geometrical requirements by having the extension apparatus suspended from a broad crossbar, as wide as the average operating table, so constructed as to permit accurate adjustment of the mechanical axis of extension to the anatomical axis. The distance between the two trochanters of the patient can be measured, and the extension bars can be placed accordingly. The apparatus can be attached bilaterally to any examining or operating table by means of strong clamps (Figs. 1 and 2). When not in use, it can be kept in a wooden case. The saving of expense and space is obvious.

The essential parts of the apparatus are the following:

1. Two removable extension bars with adjustable aluminum foot plates.

2. The crossbar, provided with a screw device which permits adjustment of the extension bars. To the crossbar is attached a horseshoe-shaped pelvic support and a perineal bar. On each side it ends in a curved arm, by means of which it can be fastened to the table.

3. An adjustable thoracic support and a head piece, both padded with felt, mounted on a light frame.

4. Two light removable suspension frames, attached to the extension bars to prevent sagging of the limb.

The extension bars are constructed on the same principle as that employed in the author's apparatus for the treatment of tibial fractures[1]. They consist of two pairs of parallel 12-millimeter round steel bars, held by two cross-ferrules. Between the bars is a screw, controlled by a key. When this is turned toward the left, the bars are made to separate; in this way, adequate extension can be secured. The position of the foot plates can be adjusted for the individual patient. The plates can also be rotated, or turned into a position permitting plantar flexion. When plaster is applied, the flat bar supporting the foot plate should not be covered with plaster. After the plaster has set, the wing screw holding the plate is loosened, and the plate is withdrawn; this loosens the plate support. When this has been removed, a depression is seen in the sole of the plaster, which can be closed with a few turns of bandage. The foot plate should be oiled before the plaster is applied, to facilitate its withdrawal. Instead of the plate, a hook may be used, to which a Steinmann nail through the calcaneus may be attached.

The crossbar can be attached to the operating table by substituting its side arms for the usual leg supports employed for the lithotomy position. The crossbar consists of two parallel 14-millimeter round bars, held securely by three transverse ferrules, one in the middle and one on each side. In addition there are two movable ferrules, controlled by a screw device similar to that used for extension. To these movable ferrules are attached the extension bars; the position of the bars can be adjusted so as to give true axial extension. To the middle ferrule is fastened the padded perineal bar and the pelvic rest.

The thoracic support is given more stability by an elliptical base which rests on the table. The head support can be raised or lowered, and, like the thoracic support, can be shifted cephalad or caudad. The frame on which the supports rest is attached to the crossbar by a removable bolt.

The suspension frames can be shifted so as to give the limbs adequate support by means of loops of bandage (Fig. 2). Axial deviations of the fractured femur can also be corrected by this means. After the application of plaster, the loops are easily cut away.

When the apparatus is used, whether for the application of plaster or for open operation, it is advisable to cover the frame with towels so as to prevent soiling, particularly of the screw devices.

1. von Petz, A.: Ein neuer Distraktionsapparat und ein neues Schienungsverfahren für Unterschenkelbrüche. Chirurg, 5: 252–259, 1933.

AMPUTATION FOR TUBERCULOSIS OF JOINTS

A Study of the Therapeutic and Prognostic Value *

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AND WALTER P. GRAUL, M.D., PHILADELPHIA, PENNSYLVANIA

From the Orthopaedic Service, Sea View Hospital, Staten Island, New York

This study was undertaken to determine the results from the removal by amputation of a massive focus of tuberculous infection in a major joint. The clinical impression at Sea View Hospital has been that amputation offers many patients a longer life expectancy, and that the clinical course improves after such an operation. However, many factors must be considered in an analysis of the results of amputation; the authors have attempted to study these factors.

A survey of the literature has revealed a marked sparsity of information on this subject. Girdlestone [1] has discussed this phase of treatment for tuberculosis of bone and joints in a more satisfactory manner than have others. He analyzed nine cases and was satisfied that the results were good in almost all of them. In fact, Girdlestone raised the same question which this work aimed to investigate, when he stated: "Is it probable that the local lesion is alone responsible for a man's illness and that relief from toxic absorption will enable the man to recover from any other lesion he may have? Or, on the other hand, is the local lesion only active because of the man's general illness, and will any operation be futile or definitely harmful?"

The general indications for amputation at Sea View Hospital during the past ten years have been:

1. To remove an extensive focus of infection in the hope of saving the life of a patient, apparently doomed;
2. To remove a focus of infection in a joint destroyed so extensively that it would be impossible to save or fuse the joint;
3. To remove a focus of intractable pain;
4. To remove a deformed hand or foot with multiple draining sinuses and no functional value.

All of these indications for amputation may exist in the same patient, or they may exist in any combination.

This study includes all patients with tuberculosis of major joints who had amputations at Sea View Hospital from 1937 through 1946 †. The only patients excluded were those with amputations of digits, on the basis that such joints do not constitute as extensive a focus of tuberculous infection as do the larger units, and, therefore, the menace to the life of the patient is a relatively minor factor.

A total of thirty-five amputations on thirty-four patients were performed during the ten-year period (Table I). Seven of these thirty-four patients are still in the Hospital under treatment and are excluded from all analyses, except those dealing with the location of the lesion requiring amputation.

Of the twenty-seven cases reviewed, death occurred in seventeen patients or 63 per cent.; the survivors numbered ten or 37 per cent. The high incidence of fatalities in this series may be explained by the fact that many of the patients were extremely ill on admission, and died shortly after admission. The authors' impression is that removal of a severe secondary focus by amputation has no beneficial effect on the general progress of an asso-

* Read before the Orthopaedic Section, New York Academy of Medicine, April 16, 1948.
† Streptomycin was not available during this period.

TABLE I

RESULTS OF AMPUTATION IN THIRTY-FOUR PATIENTS WITH TUBERCULOSIS OF JOINTS *

	No. of Cases	Sex		Race		Age Range (*Years*)	Average Age	Duration of Joint Lesion		
		Males	Females	White	Negro			Average (*Years*)	Minimum (*Months*)	Maximum (*Years*)
Deaths	17 (63%)	16 (69%)	1 (25%)	8 (57%)	9 (69%)	17–69	42	3	9	5½
Survivals	10 (37%)	7 (31%)	3 (75%)	6 (43%)	4 (31%)	20–62	40	2	6	2½

* Seven patients (six males, one female) still in Hospital.

ciated massive pulmonary lesion. Such severe pulmonary lesions were invariably the cause of death among these patients. In one case, the pulmonary lesion was responsible for death only two weeks after amputation, the operation being performed to relieve the patient of severe intractable pain in the involved joint. In over one-half of the cases, death occurred within three months.

There is a significant difference in the number of male patients having amputation, as compared with females. There were twenty-nine males but only five females,—a ratio of about six to one. The reason for this is not clear. There are twice as many orthopaedic beds in the Hospital for males as for females. The supposition is that the males in this low-income group are more active in the struggle for economic survival than the females; the male is usually the sole support of the family and continues to use his tuberculous joint long after the initial, non-disabling symptoms have appeared, whereas the female is sooner permitted to resort to bed rest, and thus gives the joint a measure of early protection.

A further comparison reveals that 69 per cent. of the cases in males terminated in death, but only 25 per cent. of the cases in females. Of the total deaths, 94 per cent. were in males, but only 6 per cent. were in females.

No significant pattern of racial distribution could be found, as there was an almost equal distribution between white and negro patients.

The age incidence reveals that children were completely exempt from the necessity for amputation. It is, of course, a universal experience that one is able to control joint lesions in children by fusion or cast immobilization far more effectively than in adults. The youngest patient in this series was seventeen years of age; the oldest was sixty-nine. There was no significant difference in the ages of those who died, as compared with those who survived.

A study of the duration of the joint lesion prior to amputation shows that, in those who survived, the lesions had been present for a shorter period of time than in those patients who died (Table I). These, of course, are average figures and could be misleading, but they do show a strong tendency for those with a relatively early lesion to have a better chance for survival. The average duration of the joint lesion in those who survived amputa-

TABLE II

LOCATION OF LESIONS REQUIRING AMPUTATION

	Knee		Foot and Ankle		Wrist		Elbow	
	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)	(*No.*)	(*Per cent.*)
Deaths	9	52	6	55	2	40	1	50
Survivals	4	24	3	27	2	40	1	50
Patients still in Hospital	4	24	2	18	1	20	0	0

TABLE III

MULTIPLE FOCI OF INFECTION

	Location of Other Skeletal Lesions						Patients with Multiple Skeletal Lesions	Patients with Single Skeletal Lesions
	Spine	Sacro-Iliac	Ankle	Sternum	Clavicle	Finger		
Deaths	3	2	4	1	0	1	7	10
Survivals	1	0	0	0	1	0	2	8

tion was two years, whereas the average duration in those patients who died was three years.

The location of the lesion which required amputation bears out the well-known fact that the weight-bearing joints are more often and more severely involved than the non-weight-bearing joints. Thus, 80 per cent. of all the lesions were in weight-bearing joints, such as the knee, ankle, and foot (Table II).

The most conclusive finding in this entire study was the close relationship between the extent of the pulmonary lesion and the eventual outcome. At Sea View Hospital, the Gaffky scale is used routinely to indicate the approximate activity of the pulmonary lesion, according to the number of bacilli per microscopic field. By the use of this scale as a basis of comparison, the sputum was found to be a remarkably accurate indication of the future death or survival of the patient. The patients who died were found almost invariably to have had positive sputa; and usually their sputa had been in the higher range of the Gaffky scale, the average being Gaffky VII, indicating very active and extensive pulmonary involvement. Thus, of the seventeen patients who died, thirteen or 76 per cent. were Gaffky positive, while only four or 24 per cent. were Gaffky negative. The findings in those patients who were discharged with arrested lesions were in marked contrast. Only one of ten had a positive sputum. The count in even this one patient was somewhat doubtful, as the bacilli were found only once in many determinations covering a long period. None of the other 90 per cent., at any time during the hospital stay, had a positive sputum.

As might be expected, the number of foci in the body had a most important bearing on the end result. Thus, every one of the patients who died was found to have at least one other focus besides that existing at the site of amputation. Thirty-five per cent. had a double focus, consisting of the osseous lesion plus a pulmonary focus; 30 per cent. had triple foci; 30 per cent. had four foci; and 5 per cent. had five or more foci. In marked contrast to this, those patients who survived almost never had more than a double focus, and these secondary foci were of a minor character, such as superficial skin lesions and epididymis lesions (Table III).

An attempt was made to study the immediate postoperative improvement following amputation. This was difficult, because such an observation would necessarily be based upon the subjective impressions of a constantly changing house staff. Therefore, the temperature curves of all these patients before and after amputation were analyzed. It was found, in those patients who died, that the temperature curves before and after operation showed no significant change. This could be expected, since each of these patients had, in addition to the joint infection, an active, extensive, pulmonary lesion. Those patients who survived, however, had no pulmonary lesion; and when the focus of infection in the joint had been removed by amputation, there was immediate improvement and the temperature returned to normal and stayed there.

This survey has shown that another indication for amputation may be added to those already given,—namely, amputation as a measure of economy for the patient, a great saving of his time and money. That this is worthy of consideration may be seen from a

study of the interval between the time of amputation and the time of discharge from the Hospital. In most of the patients this period of hospital stay was extremely short (as little as eighteen days after amputation); most of the patients left the Hospital within three and one-half months. In the treatment of such patients, fusion cannot be attempted for many months, or even years. The mental well-being of the patient is of the utmost importance, and when he knows that he is rid of his lesion, that there is no chance of a flare-up (at least in that lesion), and that his return to society is probably a permanent one, his morale is greatly improved.

In spite of the fact that many of these patients are doomed, by reason of far-advanced, bilateral pulmonary disease, the dramatic relief from severe pain in the bone lesion makes the operation worth while. Patients are very grateful for this.

The amputation sites were still draining in four of the patients who died. One of the survivors required resection of a sinus tract in the stump, ten months after amputation; when last seen, five years later, he was in excellent condition. The sites of drainage were not found to be persistent tuberculous foci, although repeated bacteriological examinations were done. There was only one case of phantom limb, and this sensation disappeared within two months.

This study did not attempt to determine what effect extensive lung resection might have on the eventual outcome of those patients with active chest lesions. However, it has become increasingly apparent that the thoracic and orthopaedic surgeons must work in close cooperation. The thoracic surgeon is unwilling to operate, unless the patient can be ambulatory the day after operation. Thus, the orthopaedic surgeon must provide him with an ambulatory patient as soon as practicable. If there is too long a delay, the pulmonary lesion may become inoperable. In large tuberculosis centers, this cooperation has proved of the utmost importance to the patient's welfare.

CONCLUSIONS

1. Amputation for extensive tuberculous infection of a joint can offer little hope of helping to save the life of a patient if he has an active pulmonary lesion.

2. The classical indications for amputation in tuberculosis remain unmodified.

3. Males require amputation for tuberculosis more often than do females.

4. The best chance for survival exists when the amputation is performed relatively early.

5. Amputation of a tuberculous, secondarily infected lesion of a major joint in an otherwise healthy patient allows an early dismissal from the hospital.

1. GIRDLESTONE, G. R.: Tuberculosis of Bone and Joint. London, Oxford University Press, 1940.

A SIMPLE AND EFFECTIVE SPLINT FOR USE IN THE TREATMENT OF CLAWING OF THE TOES

BY WILLIAM J. WILSON, M.D., WILMINGTON, NORTH CAROLINA

All of us have observed clawing of the toes in patients with low cord lesions and injuries of the lumbar spine. These patients usually present some degree of pes cavus as well, but the main complaint is difficulty in obtaining properly fitting shoes, as well as corn formation over the interphalangeal joints. The author has tried many different devices, such as beach sandals with straps, to flatten out the toes, but nearly always abrasions of the skin occurred that were slow in healing. This tendency to slow healing in such cases also contra-indicates tenotomies or other surgical procedures.

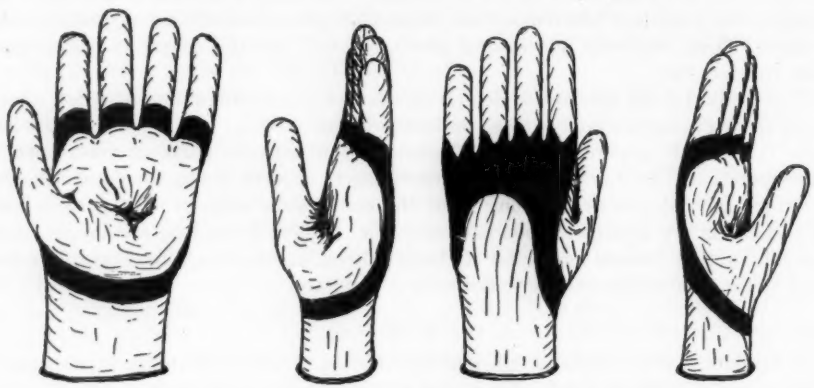

FIG. 1

Illustrates how the splint is cut from a rubber glove. The palmar, ulnar, dorsal, and radial views, respectively, are shown.

FIG. 2

Medial, dorsal, and lateral views of foot with splint applied.

A simple, efficient, and inexpensive device is presented that has proved to be of great value. Not only do the toes straighten, but the patient's walking is improved. In one case in which a tumor of the cauda equina was removed, it has been necessary for the patient to wear the device only about half the time to maintain correction. In no case has necrosis of the skin or other complication occurred.

The splint is made from household rubber gloves, which are easily obtainable from

grocery or department stores. Surgical gloves are too thin, and they tend to roll into a cord and cause constriction. This does not occur with the heavier household product. Figure 1 shows how the splint is cut from the glove. Figure 2 illustrates the splint in use. The fact that the glove has only four fingers to fit over five toes has not yet offered a problem. In one case the band from the fourth finger accommodated both the fourth and fifth toes; but usually when the first four toes are pulled down, the extensor of the fifth toe is sufficiently relaxed.

The splint offers the advantages that it can be worn comfortably under the hose in a conventional shoe, and it is not conspicuous.

DEPARTMENTAL TEACHING OF FRACTURES IN THE MEDICAL SCHOOLS OF THE UNITED STATES*

By Herman F. Johnson, M.D., Omaha, Nebraska,
and Sidney L. Stovall, M.D., San Antonio, Texas

Within the past decade the management of fractures has gained recognition as a definite phase in the curriculum of the undergraduate students in medical schools throughout the United States. The demand for doctors who are adequately trained in the complexities of fracture care has been greatly enhanced by the increasing number of traffic and industrial accidents, as well as by World War II. Thus, the study of fracture management is rapidly assuming an importance equal to that of general surgery and medicine.

At the meeting of The American Academy of Orthopaedic Surgeons in Chicago, in January 1947, it was suggested by several members of the Committee on Fractures and Traumatic Surgery, then headed by President-Elect Mather Cleveland, that a survey be undertaken of the teaching methods employed in the medical schools of the United States, with regard to fractures and dislocations. The Secretary of the Fracture Committee (H. F. J.) was asked by the Chairman to send letters to the medical schools of the United States to determine the number of hours being devoted to this subject, and which staff (general surgery, orthopaedic surgery, or a combination of the two) was held responsible for the teaching. Questionnaires were sent to seventy Class A medical schools, the questions asked being as follows:

"1. How many hours are allotted to the subject of fractures and dislocations in your medical school?

"2. Are fractures a part of the general surgical service and taught by general surgeons?

"3. On either the orthopaedic or general surgical service are fractures taught by both general surgeons and orthopaedic surgeons or by orthopaedic surgeons alone?"

The response to the questionnaire was surprisingly good, as replies were received from sixty-seven (95.7 per cent.) of the schools (Table I). In addition to answering the questions, many of the deans and department heads volunteered suggestions and recommendations, some of which are quoted herein.

It is of interest to note the growing trend in the medical schools to ally fracture work with orthopaedic surgery. Several years ago fractures, in most instances, were dealt with exclusively by the general surgical service, while today more than half of the recognized schools have correlated fracture care with orthopaedic surgery. With this tremendous interest in traumatic surgery, many young men are taking residencies and fellowships in orthopaedic surgery. Into many of these same hands the teaching of this subject will ultimately fall, and hence it is to be expected that the growing demand for the placing of this borderline subject in its proper field will become even more pronounced. This refers especially to traumatic lesions of the spine and extremities. With the sharp tendency to specialization, head injuries and traumata of the chest and abdominal viscera naturally are included among the specialties covering those particular parts of the anatomy. With the extensive definitive surgery and corrective measures often necessary in the treatment of skeletal injuries, the orthopaedic surgeon, who has qualified himself for this type of work, should have the opportunity to follow these problems from the time of the emergency care through to the final end result; in many instances this requires several years of observation. Too often the early emergency treatment has been rendered by individuals lacking the opportunity to care for these patients subsequently when delayed union, non-union, or malunion develops. These patients have then, belatedly, come under the care of the orthopaedic surgeon, who must carry on until the patient has attained his maximum improvement. Thus it would appear that, often to the detriment of the patient, the final result has been obtained in many cases in a roundabout manner, rather than by the simple process of placing such cases in the hands of qualified men at the onset.

* Report of the Committee on Fractures and Traumatic Surgery, presented to The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948. The Chairman of the Committee was Mather Cleveland, M.D., and the Secretary was Herman F. Johnson, M.D.

TABLE I

Answers to Questionnaires	Number	Per cent.
Total schools	70	100.0
Schools heard from	67	95.7
Fractures treated on orthopaedic service	40	57.1
Fractures treated on general surgical service	27	38.6
Teaching by orthopaedic surgeons	37	52.9
Teaching by general surgeons	9	12.8
Teaching by both orthopaedic and general surgeons	22	31.4

Forty of the schools replying (57.1 per cent.) stated that fracture cases were treated on the orthopaedic service, while in twenty-seven instances (38.6 per cent.) it was reported that fracture cases constituted a part of the general surgical service. The significance of these figures is self-evident when one considers the rapid advances made within this field during the past ten to twelve years. It should further be observed that, of the twenty-seven schools designating fracture care as part of the general surgical service, twenty schools divided the cases with the orthopaedic service. To illustrate this general trend toward the emergence of fractures as a purely orthopaedic problem, the following notation, taken from the letter received from James R. Martin, Professor of Orthopaedic Surgery at the Jefferson Medical College of Philadelphia, seems indicative: "Lectures are given by the general surgeons and the practical work by the orthopaedic surgeons. Naturally the Orthopaedic Department would like to have the whole problem of fractures placed in their hands. Up to five years ago the Orthopaedic Department in our institution had no part in the teaching or practical work of fractures. We now treat all the fractures and are teaching the practical side." Thus it is seen that even within the twenty-seven schools adhering to the old method of assigning fracture cases to the general surgical service, the majority have conceded at least half of the fracture service to the orthopaedic department.

The Teaching of Fracture Management

It was reported by thirty-seven schools (52.9 per cent.) that the instruction of undergraduate students was assigned exclusively to the department of orthopaedic surgery. Twenty-two schools (31.4 per cent.) reported their teaching to be carried out jointly by the orthopaedic and general surgical departments. Only nine schools (12.8 per cent.) confined the teaching of fractures to the general surgical department. Within this latter group, five schools reported that the general surgeons directing fracture instruction were required to have special qualifications in this field. One college anticipated establishing an orthopaedic service, at which time the subject of fractures and dislocations would be turned over to that department entirely.

Of the twenty-two institutions in which fracture teaching entailed the efforts of both the general surgical and orthopaedic staffs, six reported an equal division of the work; eight failed to give specific details; one school, the College of Physicians and Surgeons, Columbia University, proposed to have its instructors certified by both the American Board of Surgery and the American Board of Orthopaedic Surgery; six schools stated that the majority of the instruction fell to the orthopaedic department; and one school relegated approximately two-thirds of its instruction to the general surgical service. In this regard the remarks of O. H. Wangensteen, Chief of the Department of Surgery at the University of Minnesota Medical School, seem pertinent: "Dr. Zierold and I have discussed the general management of the fracture problem from the standpoint of teaching students. Dr. Zierold is of the impression that teaching is a formal course in fractures, and is not a responsibility that can be divided. That is, it should be taught either by the general surgeons or by the orthopaedists."

Within the group of schools delegating fracture instruction to the orthopaedic department, six included fractures and dislocations in the general course of orthopaedic surgery and the subject was in no way segregated.

Freshman Instruction: Only three schools included the study of fractures and dislocations in the freshman curriculum. The University of Louisville Medical School conducts a sixteen-hour course in splinting and first-aid treatment; at the College of Physicians and Surgeons, Columbia University, six hours of clinical work are presented in conjunction with the course in anatomy. The patients shown are those evidencing poor anatomical or functional results, in an effort to illustrate to the students the importance of a sound knowledge of anatomy. The University of Texas School of Medicine also reported the discussion of fractures in conjunction with the anatomy class, at which time the architectural features of bone are stressed. The subject of bone repair is introduced in the freshman year in connection with histology classes. In view of these facts, it is to be concluded that consideration of fractures this early in the undergraduate work is deemed inadvisable by the great majority of the schools.

Sophomore Instruction: Thirteen schools reported the institution of fracture work in the sophomore year. The teaching during this period consists primarily of didactic lectures, although one school reported the incorporation of six hours of clinical lectures at the hospital; one school, five hours as assistant in the out-patient

department; and two schools introduce instruction in casting and the use of orthopaedic appliances in conjunction with the sophomore training program. The maximum time allotted to this subject during this phase of undergraduate study is twenty-seven hours, twenty-two hours being engaged in didactic lectures and five hours employed in out-patient work. Of the schools teaching fractures in the sophomore year, the minimum time relegated is one hour. Nine schools devote more than ten hours to the subject, while four schools devote less than ten hours. Fifty-four schools give no consideration to the subject during the sophomore year.

Junior Instruction: During the junior year, the undergraduate students first face the actual problems of fracture treatment in the majority of the medical schools. Seventeen schools reported their teaching programs within this period to include a combination of didactic lectures and clinical activities on the wards, in the operating rooms, and in the out-patient departments. The maximum period of training during the junior year within this group consists of thirty-three hours of didactic instruction and eleven hours of clinical study; the minimum amount of time allotted encompasses four hours of lectures and an unspecified number of clinical hours, covering a period of one quarter; while the average is sixteen didactic hours and twenty clinical hours. Eleven schools restrict fracture instruction in the junior year to a course of didactic lectures, the maximum time allotment within this group being that of the University of Virginia School of Medicine, which specified forty hours of didactic study. The average time commitment was given as approximately sixteen hours and the minimum was represented as ten hours. Four schools reported confining their fracture study to clinical work. As the majority of schools falling within this group did not specify the exact number of hours devoted to the clinical study of fractures, it was rather difficult to make an accurate estimate of the time allotted to fractures. Columbia University requires each junior student to be on call twenty-four hours a day for a period equaling three weeks. The University of Rochester School of Medicine conducts clinical teaching for a period of 110 hours during the junior year.

Senior Instruction: Senior fracture training is comprised primarily of clinical work, the didactic training having been accomplished before this time; however, in some schools the subject of fractures is not introduced until the senior year. Seven schools fall within this latter category. Twelve schools, in addition to the work done in the previous years, continue to present didactic lectures as well as clinical activities. Only three schools which had presented work on fractures in previous years stated that they restricted the senior activities to didactic lectures. Twenty-one schools reported that the fracture study assigned to the senior class consisted entirely of clinical work. Three schools reported that no fracture work of any type was done in the senior year, and nineteen schools failed to comment on the requirements imposed upon the senior students with regard to the study of fractures and dislocations.

Within the first group of schools, the seven introducing fracture work in the senior year, one covers the subject entirely by means of didactic lectures; one confines study of the subject to the fracture work appearing on a general surgical ward during the student's clerkship; and five combine didactic and clinical studies. Twenty-two hours of lectures represent the maximum didactic course, and twelve hours the minimum as well as the average number of hours. The greatest period of time devoted to clinical work is fourteen hours, but as the remaining six schools failed to enumerate accurately their proportionate studies, the average and minimum periods could not be determined.

Within the second group of schools, those continuing combined clinical and didactic studies, the greatest period devoted to didactic lectures is twenty hours, the minimum four hours, and the average approximately twelve hours. The longest period of time relegated to clinical activity comprises forty-eight hours. An average could not be obtained, as no common medium in work estimation had been established.

Within the third group, that of twenty-one schools which restricted senior fracture study to clinical work, the greatest period of time spent in this instruction was reported to be seventy-two hours and the minimum eight hours. Again an average could not be reached, although it was considered to be in the vicinity of eighteen hours.

Comments

In reviewing the comments made by thirty-four of the deans and department heads, a definite impression was gained that the treatment of fractures and dislocations was an ever-expanding field which merited special consideration. This was aptly expressed by H. Bernard, Professor of Orthopaedic Surgery at the University of Colorado School of Medicine, who wrote as follows: "In my opinion the ideal way would be to have a fracture service with a qualified orthopaedic surgeon in charge. Or, if a general surgeon were qualified and desirous of teaching, he might be appointed to the fracture service. However, as a rule, a general surgeon cares only about fractures in the medical school up to the point where he has learned as much as he thinks he will on the subject, and then he is willing to release the place to another general surgeon. It would be more efficient and better for the students if those teaching fractures were orthopaedic surgeons, I believe."

In several instances fracture problems and the vast number of fracture cases induced by World War II were mentioned to illustrate the increasing concern with this controversial division of surgery. For example, Acting Dean H. Boyd Wylie, of the University of Maryland School of Medicine, wrote: "We are not entirely satisfied with our present method of teaching fractures and dislocations and are constantly making improvements. With the experience and knowledge of many of our younger men who have returned from military service, and the applications of the knowledge, we believe we are making good progress."

In only one instance was an opinion expressed to the effect that fracture care and the teaching of fractures should fall under the specific direction of general surgeons, while in eight of nine instances it was specified that fracture care should be considered a part of the orthopaedic service and taught by orthopaedic surgeons. In each of the eight cases just mentioned, the preference for orthopaedic control of fracture work proceeded from schools where fracture instruction was under the auspices of the general surgical department. The following pertinent opinion was expressed by J. A. W. Hetrick, Dean of the New York Medical College: "We believe that fractures are best taught by the Orthopaedic Department, for this group takes more interest in fractures and has a better background for the proper understanding of skeletal injuries."

With regard to the method of teaching fracture care to the undergraduate students, it was the prevailing opinion that clinical teaching was more beneficial than didactic teaching. Repeatedly throughout the reports, with only three exceptions, the superiority of clinical instruction was emphasized as being paramount, although didactic instruction in the rudimentary principles was, of course, accepted. Thus it would appear that didactic instruction could safely be restricted to a minimum period of time and the hours of clinical activity could be proportionately increased. In two instances it was believed that each student should have the greatest possible opportunity to participate in the treatment of fracture cases. It was further concluded by the majority of schools that the study of fractures and dislocations should be deferred until the junior and senior years, although two schools advocated frequent mention of fractures during anatomy classes and one school recommended that fracture instruction be confined to the senior year. G. Mosser Taylor of the College of Medical Evangelists wrote as follows: "This is one subject which is difficult to teach from a textbook, although such a course, with the visual aids that are now available, will be of some value to the student. However, the best teaching is clinical."

Eleven of the reports received forcefully brought out that fracture management, as any other surgical treatment, was primarily a postgraduate field; and that, in preparation of the program of study to be presented to the undergraduate student body, this must be kept in mind. The late E. M. MacEwen, Dean of the State University of Iowa, expressed the following opinion: "I am more and more convinced that in the not-too-distant future such subjects as orthopaedics and many of the other specialties in surgery will become almost entirely postgraduate fields. To a great extent I think we are wasting our time in undergraduate years by giving so many courses, even though they are short. In fact, outside of surgical diagnosis and emergency work, I would be very much in favor of seeing all general surgical subjects put in the postgraduate period. I do not consider that we should expect the student to handle fractures adequately during his undergraduate training. Emergency work in this field should be taught. In other words, the individual should be in a position to act in the emergency room during his internship."

Contrary to this, seven schools were of the opinion that fracture study should be as extensive as time permitted in the undergraduate curriculum, especially in view of the fact that most doctors practising in small communities where specialization is limited will be called upon for emergency fracture work. Thus it was the opinion of this group that a study of fractures during the undergraduate period, as well as the routine postgraduate training, was indicated in order to equip the student to meet adequately the requirements of emergency fracture management.

The impression gained from this report is that medical students would receive a better conception of emergency care and definitive treatment of fractures, dislocations, and their complications, if the instruction were given by those men best qualified to do the entire job,—men who were interested in following those complicated, prolonged cases which necessitate various plastic procedures on soft tissue and bone.

Metastatic Adenocarcinoma of the Talus

BY E. W. JOHNSON, JR., M.D., AND JOSEPH M. JANES, M.D.

(*Continued from page 184*)

Mayo, C. W., and Schlicke, C. P.: Carcinoma of the Colon and Rectum. A Study of Metastasis and Recurrences. Surg., Gynec., and Obstet., **74**: 83-91, 1942.

Mechling, C. C.: Observations on Metastasis in Rectal Cancer. Trans. Am. Proctol. Soc., **41**: 223-227, 1940.

Turner, J. W., and Jaffe, H. L.: Metastatic Neoplasms. A Clinical and Roentgenological Study of Involvement of Skeleton and Lungs. Am. J. Roentgenol., **43**: 479-492, 1940.

Weston, S. D.: Metastasis to the Humerus from Carcinoma of the Rectum. Am. J. Surg., **57**: 531-535, 1942.

A CONFERENCE OF TEACHERS OF ORTHOPAEDIC SURGERY*

FOREWORD

Following the report of the Committee on Undergraduate Training of The American Orthopaedic Association in June 1947, it was decided to hold a Conference of Teachers of Orthopaedic Surgery for the purpose of discussing the problems of undergraduate orthopaedic education. Invitations were sent to the deans of four-year medical schools in the United States, medical schools of Canada, the Association of American Medical Colleges, and the Council on Medical Education and Hospitals of the American Medical Association to send representatives to a conference of orthopaedic teachers, to be held in conjunction with the combined meeting of the American, British, and Canadian Orthopaedic Associations in Quebec, Canada, on June 5, 1948. This Conference was held as planned, under the chairmanship of Dr. A. Bruce Gill of Philadelphia.

There were 155 in attendance at the Conference, with representatives present of fifty-five of the seventy four-year medical schools in the United States, eight of the nine Canadian medical schools, and, in addition, many representatives of the medical schools of Great Britain. The transactions of the Conference have been edited by the Secretary of the Committee. All transcriptions of the discussions, with three exceptions, have been corrected by the speakers. In several instances it was impossible for the recorder of the Conference either to obtain all remarks or to render an accurate transcription of the remarks obtained; this is to be regretted. In these instances most of the speakers have prepared other remarks pertaining to what was said. Due to the lack of time at the Conference, it was impossible to hear from all who wished to speak. These were asked to send in their remarks to the secretary; two have done so. These are included in the transactions.

In preparation of the program, it was thought advisable to select speakers to open the discussions on the four main topics selected for discussion at the Conference, which were: (1) Objectives of Teaching, (2) The Curriculum, (3) The Use of Audio-Visual Aids, and (4) The Relationship of the Division of Orthopaedic Surgery with the Other Divisions in the Medical School. In arranging the transactions for publication, it has been impossible to divide all of the discussions according to subjects, as many of the speakers discussed two or more of the topics.

It is the hope of the Committee that these transactions and the 1947 Committee report, which was distributed at the Conference, may act as a guide to the deans of the medical schools and the teachers of orthopaedic surgery in the planning for the curriculum of undergraduate orthopaedic education.

Committee on Undergraduate Training
LEROY C. ABBOTT
JOSEPH S. BARR
GUY A. CALDWELL
FREMONT A. CHANDLER
PAUL C. COLONNA
JOHN L. MCDONALD
A. R. SHANDS, JR., *Secretary*
A. BRUCE GILL, *Chairman*

INTRODUCTORY REMARKS

BY A. BRUCE GILL, M.D.

In 1944, The American Orthopaedic Association established a committee to study the question of Undergraduate Teaching in Orthopaedic Surgery in the medical schools of the United States. This action was taken because it was realized that the importance of orthopaedics in the field of surgery was not universally recognized and appreciated by the medical schools, and that there was a great diversity in the medical schools in the number of hours allotted in the curriculum to the orthopaedic departments and in the selection of material and methods for teaching orthopaedic surgery to the undergraduate student.

The objectives of this Conference are: (1) to formulate an ideal course for the teaching of orthopaedic surgery to undergraduate students, bearing in mind the essential difference between undergraduate and graduate teaching; (2) to discuss methods of instructing and training the students efficiently; (3) to coordinate the teaching of orthopaedic surgery with other departments of teaching in the medical school; and (4) to seek a proper balance of orthopaedic surgery among other departments of teaching.

Your Chairman believes that we should enter into our discussions not only as instructors in orthopaedic surgery, but also as educators in medicine. We should not be carried away by enthusiasm for our own particular branch of surgery, but should try to determine what reasonable part orthopaedic surgery should

* Conducted at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 5, 1948.

have in that broad and solid foundation of undergraduate teaching upon which every practitioner of medicine and its many specialties may build the edifice of his career. We should confine our teaching largely to the presentation of basic principles and basic facts, and to training the student in methods of complete and efficient examination of patients. The opportunity to teach the student how to use his eyes and his hands in physical examinations is not surpassed in any other field of surgery.

It is probably too much to hope that a complete system of undergraduate orthopaedic teaching can be formulated, with which all will entirely agree. We are confident, however, that the fundamental principles will emerge clearly in this Conference.

THE OBJECTIVES OF UNDERGRADUATE ORTHOPAEDIC TEACHING

By A. R. Shands, Jr., M.D., Wilmington, Delaware

Alfred I. du Pont Institute

The teaching of a specialty to an undergraduate student presents one of the greatest challenges in medical education today. For the student to become a doctor, he must learn the basic medical sciences and the clinical practice of medicine in the short period of four years. The learning of a surgical specialty cannot help but be considered by him to be a minor part of his medical education. If, during his undergraduate period, he is not stimulated to acquire a fundamental understanding of a specialty, he will be graduated with a minimum of knowledge as well as with a minor interest in this field of medicine. The purpose of this discussion is to present an analysis of the objectives of the teaching of orthopaedic surgery to the undergraduate student, as reported on the questionnaires sent to the seventy four-year medical schools in the United States in 1946 by the Committee on Undergraduate Training, as well as to present the four objectives which the author believes to be the most important.

First, an analysis of the answers to Question 8 on the questionnaire sent to the four-year medical schools. This question was: "State briefly what you consider to be the main objectives in the teaching of orthopaedic surgery to the undergraduate student". Replies were received from the heads of sixty-six orthopaedic departments of these seventy schools. In the replies, thirty-two different ideas were expressed. The nine objectives mentioned most often, in order of frequency, are as follows:

1. The recognition of the more common bone or joint disorders (in thirty-nine replies or 59 per cent.). Three of this number mentioned particularly the early recognition of these conditions and two the differential diagnosis.

2. The fundamental principles of the treatment of bone and joint disorders (in twenty replies or 30 per cent.). Two replies spoke of the mechanical principles of treatment, one of the operative principles of treatment, and three stated that under no circumstances should details of operative or non-operative procedures be given to the undergraduate student.

3. The teaching of orthopaedic surgery as related to the general practitioner (in eighteen replies or 27 per cent.). Three of this number mentioned an outline of orthopaedic disorders for the general practitioner; six, a sufficient knowledge of orthopaedic surgery for the general practitioner; eight, an ability to refer difficult cases to the orthopaedic specialist; one, the principles of therapy of fractures for the general practitioner; and one, recognition of the orthopaedic conditions for which the general practitioner will be caring.

4. The diagnosis and treatment of fractures (in fifteen replies or 23 per cent.). Particular reference was made in one each to the teaching of the uncomplicated fracture, the diagnosis of fractures, the immediate treatment of fractures, and the complication of fractures.

5. The general management of the more common bone and joint disorders (in fifteen replies or 23 per cent.).

6. Teaching of how to perform an orthopaedic examination (in seven replies or 11 per cent.).

7. Teaching of the methods of prevention of deformity and disability (in seven replies or 11 per cent.).

8. Teaching of orthopaedic and related pathological findings (in seven replies or 11 per cent.). Emphasis was placed in some of the replies on teaching a basic knowledge of pathology, and on the correlation of the pathological with the clinical findings.

9. The basic knowledge of the musculoskeletal system, particularly the anatomy of bones and joints, and a correlation of this anatomy with the clinical findings (in five replies or 8 per cent.).

Other objectives which were mentioned from one to three times were: the relationship of orthopaedic surgery to general medicine and surgery; the general scope of orthopaedic surgery; a basic understanding of the field of orthopaedic surgery; an orientation into the problems of orthopaedic surgery; the prognosis of orthopaedic conditions with proper treatment, and the possibilities of their being corrected; how to take orthopaedic histories; a recognition of the normal function of bones and joints; what orthopaedic surgery can accomplish in the preservation and restoration of function; a knowledge of the bacteriology, physiology, and rehabilitation of the orthopaedic patient; making the student conscious of orthopaedic surgery; arousing

in the student an interest in common orthopaedic problems; stimulating the student to further study; office procedures for orthopaedic surgery; and the historical development of orthopaedic surgery.

The author believes that the following four objectives for the teaching of orthopaedic surgery to the undergraduate student are the most important, in the order given:

The first objective should be to give an accurate knowledge of the scope of orthopaedic surgery. Orthopaedic surgery has been defined "as that branch of surgery especially concerned with the preservation and restoration of the functions of the skeletal system, its articulations and associated structures". An interpretation of this definition and all that it implies should be presented clearly to the student.

The second objective should be instruction in how to take a satisfactory orthopaedic history and how to perform an adequate orthopaedic examination. Instruction should be given in physical diagnosis or the art of performing an examination.

The third objective should be a description of the more common bone and joint disorders, presented in such a way that these can be recognized and differentiated from conditions which more rightly belong to other fields of medicine,—that is, the differential diagnosis of the specialty.

The fourth objective should be the teaching of the fundamental principles of therapy.

As the goal of undergraduate medical education is to train and develop the student into a doctor, with knowledge of all fields of medicine and with the ability to become a good general practitioner and not a specialist, it is the belief of the author that, if these four objectives can be attained in teaching, the student will have sufficient knowledge when he graduates to enable him to screen his patients and to decide what types of conditions he can treat and what types should be referred to the specialist. By far the greatest volume of orthopaedic surgery is performed today and always will be performed by the general practitioner, and not by the specialist. A careful and thoughtful practitioner, who knows his limitations in specialty practice and when to refer the patient to the specialist, is one of the best assets to the practice of medicine a community can have. The aim of the undergraduate medical school is to create this type of physician.

The objectives of the teaching of orthopaedic surgery to the undergraduate have not changed since orthopaedic surgery became a specialty, and they are not likely to change. However, the techniques of this teaching have changed through the years. The audio-visual aids, which now are being used in most medical schools and which will be used more often and more widely as time goes on, enable the teacher to present the subjects more clearly. These aids make the learning easier for the student and the attainment of the objectives of teaching more effective.

About 1900, Dr. Edward H. Bradford of Boston, one of the great pioneers and early teachers of orthopaedic surgery, said that orthopaedic surgery is imperfectly understood; few physicians feel competent to practise it; and an objective of the orthopaedic surgeon should be to develop the specialty to the point that the mastery of this particular branch of medicine would be a requisite in the education of every physician. Today an objective of undergraduate instruction is not teaching of the student to the point of mastery of this branch, and certainly not to the point of competence to practise the specialty; but the instruction should be given to the point at which the specialty is so well understood by the student that he may feel at his graduation from medical school he has the competence to identify the more common orthopaedic conditions and to know their treatment.

DISCUSSION

By Carl E. Badgley, M.D., Ann Arbor, Michigan

University of Michigan

I am in full accord with the four objectives which have been mentioned, but I think there is a fifth objective which is far greater in importance than all four; that fifth is the stimulus to the student. I have purposefully taught orthopaedic surgery with the hope that I would show to the students the possibilities of research and stimulate an investigative interest in medicine.

Several years ago, I was invited to give an informal talk in Galveston to the senior medical group at the University of Texas. Two distinguished doctors were also on the program. They both had excellently prepared scientific papers with lantern slides on investigations in medicine. The students, I am sure, were rather bored, yet thought it was part of their prescribed work to sit and listen. I am sure, however, they thought that here were two outstanding men who were doing something that they could never do. I attempted to show the students that in all probability neither of those men had started out in medicine with the intention of producing the paper which he had just given, but that they had a curiosity for knowledge and for learning which had led them through hardships and difficulties to the final beautiful productions which they had presented.

An excellent speech was given recently at a McGill University graduation exercise in which it was said that "knowledge without wisdom, and the will to use it, is sterile".

In conclusion, I would make a plea for this fifth objective and, to my mind, the most all-important of objectives of orthopaedic teaching,—to stimulate in young men the ability to recognize that they have a far better basic background than their teachers had, and a far better potentiality for the development of knowledge in medicine, of which just the surface has been scratched.

THE WELL-BALANCED CURRICULUM IN ORTHOPAEDIC SURGERY

By Robert W. Johnson, Jr., M.D., Baltimore, Maryland

Johns Hopkins University

After hearing Dr. Shands' keynote address, amplified as is necessary to get any convention under way, and also with the consciousness that I'll be followed by Dr. Green, who has a well thought-out and detailed program to offer, I begin to wonder what there is for me to say. I have been very lucky in that I have not had to fight for time in which to teach orthopaedic surgery. My predecessors at The Hopkins, especially Dr. Baer and Dr. Bennett, fought and won numerous battles years ago, the first in respect to pure orthopaedic surgery, the latter with respect to fractures and dislocations. They won them not because they wanted to teach, but because they could teach and interest the students in their subjects.

This brings me to the issue that I particularly wish to stress,—namely, the great difference between teaching of orthopaedic surgery to the undergraduates, or medical students as I prefer to call them, and the postgraduate training of orthopaedic surgeons. To undergraduates, we must be doctors; to postgraduates, specialist surgeons. If we are specialist surgeons to the undergraduates we are completely out of focus, and our teaching will be blurred and soon forgotten.

We must see ourselves and our specialty in relation to medicine as a whole. That places upon us the burden of making the student conscious of the neuromuscular-skeletal system as a functioning part of the individual patient as a whole, and not only of explaining to him its normal functions, but of recognizing the abnormalities and diseases affecting this complex system and giving a very brief outline of the principles of treatment of such malfunctioning. The realm of orthopaedic surgery literally covers the entire body and brings us into contact with the brain, heart, lungs, endocrines, et cetera. As far as undergraduate teaching is concerned, we have the job of integrating our field with all the other fields of medicine, including to no small degree the field of psychiatry.

Differential diagnosis, therefore, should be our keynote, using diagnostic methods with special reference to full inspection, gait, posture, mensuration, muscle testing, et cetera. These things stimulate the student's thought by giving him means of getting more information for himself than he is apt to get from the usual course in physical diagnosis.

How can we best accomplish this purpose of integrating ourselves with general medicine? Let us consider the four years of medical school. In the first year, the course in anatomy keeps the neuromuscular-skeletal system before the student, and even the bones are apt to get more attention in this course than they get in later preclinical courses, such as pathology. I see no need for orthopaedic surgery to make inroads into the students' time in this year, except for a lecture-demonstration on functional or surgical anatomy, with the idea of showing the student some of the practical implications of his anatomical studies.

The second year is the introduction of the student to clinical medicine in most schools. I am satisfied in this year with a very short, but I hope sharp, attack on the students in physical diagnosis, giving them gait, posture, deformities, and the secondary effects therefrom. Two hours will do. An hour or two as a refresher course in anatomy of the surgical type will be useful to those students leaning toward surgery.

In the third year, we come to the practical surgery. In this year we are expected to deal with the concrete subjects of fractures and dislocations. This is the course I am the most uncertain about as it is now organized. I think that Hopkins was the first school to delegate this subject of fractures and dislocations to the orthopaedic staff, both in teaching and management.

Obviously, ideal teaching should be clinical, but practically it must be didactic in order to cover the subject, with as much clinical material included as possible. Somehow, fractures of the femur seem to occur only in the weeks that we have to deal with Colles's fractures, and vice versa. We are still fumbling with this problem, but despite the difficulties, Dr. George Eaton is doing a good job in seeing that even the embryo gastro-enterologist knows how to recognize and treat the fracture on the spot.

Sixteen required lecture-demonstrations, plus voluntary attendance at the weekly fracture clinic and a sort of obstetrical call service for acute fractures in the accident room, comprise this course.

We also supply a consultant to the medical-surgical diagnostic clinic, through which all new patients pass and thus come in contact with the third-year student in the general diagnostic work-up.

The fourth year is the year of refinement and polish. Here we have a twofold program. The first part consists of sixteen lectures in a systematic presentation of major orthopaedic subjects—poliomyelitis,

tuberculosis, scoliosis, arthritis, et cetera—which are allocated to various members of the staff with the idea that each will present his special interest and enthusiasm to the student more fully than I could. I believe that this has a stimulating effect on both the students and the staff.

In addition, there are weekly ward rounds with the small groups of students in their surgical quarter, and this means eight hours for the students and covers about twenty or thirty cases of all kinds from the wards and the Children's Hospital School. Stress here is on differential diagnosis, integration of orthopaedic findings with the laboratories, the other surgical specialties, medicine in general, psychiatry, and biochemistry. Splinting after-care, occupational therapy, and physical therapy are stressed more than surgical procedures, although principles of surgical approach are discussed. Attendance at operations is voluntary.

This, briefly, is our set-up and the philosophy behind it: first to keep before the student the neuromuscular-skeletal system as an important part of the patient he is going to treat; second, to perfect the student in observation and examination; third, to give him some additional skill in differential diagnosis; fourth, to acquaint him with the possibilities of treatment, conservative and operative, of such orthopaedic problems as he may encounter in his career as a physician, surgeon, or investigator; and fifth, to interest the exceptional student in an orthopaedic career.

THE WELL-BALANCED CURRICULUM IN ORTHOPAEDIC SURGERY

By William T. Green, M.D., Boston, Massachusetts

Harvard University

When we as orthopaedic surgeons face the problem of a balanced curriculum, we are likely to be biased as to the importance of orthopaedic surgery in undergraduate teaching and the amount of time which should be allotted to it. However, it is quite obvious to all of us that in many schools, at least, orthopaedic surgery does not receive its due. In most schools, a representative of the department of orthopaedic surgery does not serve on the curriculum committee, nor does he have any voice in the final decisions of this committee. Often to those serving in such a position, orthopaedic surgery represents a specialty of very limited nature, and it is awarded the same amount of time as is given to a specialty limited in scope and confined to one small anatomical area. My remarks are made with the understanding that orthopaedic surgery is a major branch of surgery and that the problems in this field are some of the most common in medical practice. Orthopaedic surgery has ramifications extending into all branches of medicine and surgery, and much of its special knowledge is pertinent to the balanced education of a medical student. By its nature, orthopaedic surgery lends itself to the teaching of general surgical principles better than do most divisions of surgery. It is well to comment here that the purpose of undergraduate teaching in orthopaedic surgery is not to produce orthopaedic surgeons, but rather to teach those basic principles which are essential to a balanced education.

It seems to me that somewhere between 20 and 25 per cent. of the teaching time in surgery should be assigned to the department of orthopaedic surgery. If this means an increase in the amount of time devoted to orthopaedic surgery in an existing schedule, the additional time would not necessarily come from that allotted to teaching in general surgery. It might come from various adjustments. Furthermore, if the department of general surgery teaches things which ordinarily should be under the department of orthopaedic surgery, such as fractures and bone tumors, the instructional time assigned to orthopaedic surgery may be reduced proportionately. Such instruction should, however, be carefully correlated with the teaching in the orthopaedic department.

One of the main difficulties, other than that too little time is allotted to orthopaedic surgery, is that it is frequently worked into the curriculum in haphazard fashion, so that it is impossible to develop a reasonable integration either vertically or horizontally. Frequently lectures in the clinical years are scheduled without regard to the time of sectional instruction. This greatly decreases their value. In our experience, students arrive for their assignment to the Department of Orthopaedic Surgery in the third year with little background leading to its understanding. The time to start the teaching of orthopaedic surgery is in the first year. The head of the department should see that the courses in basic science present that material which is pertinent to future understanding of the specialty. Furthermore, the Department of Orthopaedic Surgery should itself take part in first-year and second-year teaching, which should be correlated with the instruction given in the departments of basic science.

I should like to present a sample curriculum, merely to consider general principles so that we have something specific to discuss. The details of curriculum must be modified to meet local circumstances.

The First Year

In the first year, instruction by the department of orthopaedic surgery should be correlated with the work in anatomy and physiology. Six or seven lectures may be given, as follows:

1. General: musculoskeletal system, body mechanics.
2. The trunk and neck; the back.

3 and 4. Upper extremities.
5 and 6. Lower extremities; gait.
7. Abnormalities in embryological development; bone growth.

All of these lectures, and they should be well illustrated, should stress normal musculoskeletal mechanisms which, in their presentation, may be emphasized by illustrations of abnormal states. Visits of the orthopaedic surgeon with the students in the dissection room at appropriate times is also most helpful.

The Second Year

If pathology has been taught in the first semester of the second year, it is desirable to have a schedule of orthopaedic exercises in the second half year. These should be designed to acquaint the student with a basic concept of abnormalities of the musculoskeletal system and to show him patients with these problems. Ten lectures, appropriately illustrated, might be given during this second year and might be listed as follows:

1. The problems arising in the musculoskeletal system; examination of a patient.
2. The trauma of bones.
3. Infections of bones.
4. Joint phenomena, infection, trauma; tendons, bursae, and tendon sheaths.
5. Abnormalities of growth, tumors.
6. Paralysis.
7. Developmental and congenital diseases and abnormalities.
8. Mechanical abnormalities.
9. Metabolic disease (probably by division of medicine).
10. Therapeutic measures, general, in relation to pathological processes; traction, casts, exercises, et cetera.

In addition to these lectures, there should be sectional work in physical diagnosis of the musculoskeletal system, taught by an orthopaedic surgeon. These sections should not contain more than six students for certain of the activities, but the sectional work may well be combined with demonstrations in larger groups, if it is feasible and can be correlated as to time. There should be approximately four exercises,—that is, four mornings of sectional instruction in relatively close continuity, occupying a total of twelve hours. In addition to these exercises, it is highly desirable to arrange for a single visit of each section for two to three hours to the orthopaedic out-patient department to illustrate the problems that arise. This visit should be supervised by an instructor, as should another morning exercise at which the section should make ward rounds to see the problems that are represented and the techniques of treatment. Another exercise may well be instruction in basic first-aid, bandaging, and other details, if they are not otherwise covered in the curriculum. In all, then, we have had nine or ten lectures of one hour each, and six morning sectional periods of three hours each, totaling eighteen hours of sectional work and ten hours of lecture.

The Third Year

This is the time when the students become more intimately acquainted with the patient, with orthopaedic surgery, and with the problems of the musculoskeletal system. The purpose is not to teach orthopaedic surgery as a specialty, but to give an understanding of the musculoskeletal system in its relation to the patient as a whole, which is applicable to medicine in general.

The third year should emphasize sectional work with patients, but some teaching can well be performed in large groups, particularly with visual aids. There is much to be said for and against the lecture including whole classes at this time. Such a lecture is likely to be delivered by a stimulating, capable individual, whereas, if all the teaching is done in small sectional groups, there is constant repetition, requiring a great extravagance of instructors' time. The result is that the teachers for such groups are not so stimulating or effective as those who might give a lecture to a larger group. A good portion of the work must be sectional, but part can be well covered in lectures. The difficulty of lectures to a large group is that they are likely to be entirely independent of the sectional work as to time. This is not good. The ideal would be to present the subjects, well illustrated and in lecture form, to the whole group and to correlate the sectional work with it; this is usually impossible. A good compromise is to have sections of moderate size, perhaps a fifth or a sixth of the class for certain of the exercises amounting to lectures and demonstrations, and smaller subdivisions of approximately six students assigned to each instructor for work with patients. How this can be arranged depends upon the local environment. Translated into detail, there could well be about twenty lectures or exercises corresponding to lectures. These should be as intimate as can be evolved. These lectures might be tentatively listed as follows:

1. The patient and the musculoskeletal system.
2 and 3. Congenital anomalies (specific problems, congenital hip disorders, club-foot, other anomalies).
4. Developmental diseases (miscellaneous, coxa plana, slipped epiphysis, et cetera).
5, 6, and 7. Neuromuscular abnormalities, including poliomyelitis, obstetrical paralysis, cerebral palsy, et cetera.
8 and 9. The joints: arthritis, trauma, other conditions.

10. Specific infection of bone,—osteomyelitis, tuberculosis.
11 and 12. The back: the spine, including cervical spine, mechanical difficulties, back pain, sciatica, scoliosis.
13. Tumors and related abnormalities.
14. Upper extremity, general.
15. Lower extremity, hips to knees inclusive.
16. Leg and foot.
17. Fractures: general management, simple, compound.
18. Fractures, upper extremity.
19. Fractures, spine.
20 and 21. Fractures, lower extremity.

Correlated with these lectures, as mentioned, should be sectional work involving time on the wards and in the out-patient department. The student should have a chance to work with patients in small groups with adequate supervision, assistance, and independence. This sectional assignment should approximate four weeks and should certainly not be less than three weeks.

The Fourth Year

In our experience this has been planned in correlation with general surgery, when the students have their long sectional assignment in this field. If four months are assigned to surgery, the student's total time in orthopaedic surgery, including fractures, should be not less than two weeks. Depending upon the local situation, this can be arranged by assigning the students to the orthopaedic department for two weeks, allowing the students so assigned to make the major teaching rounds on the general surgical service during this period, if possible. Likewise all the students in the large surgical section should make regular teaching rounds with the orthopaedic service, perhaps once a week. If cases on the two services are in the same wards, the cases on the orthopaedic service may be assigned to the students in rotation, and the work in orthopaedic surgery may go on synchronously with that in general surgery. The students should be responsible for the work-up of patients, they should "scrub up" for the operations on their assigned cases, and participate in all the activities affecting these patients. In addition, it is our belief that one month of elective orthopaedic surgery should be offered in the fourth year, during which a student may have an opportunity to work with the department, performing many of the duties of a junior house officer.

It has not been our purpose to outline these details with the idea that they should be followed, but merely to represent a pattern of instruction and to emphasize that the teaching of orthopaedic surgery should start in the first year and should be gradually woven into the fabric of the curriculum.

The object should not be merely to teach the facts in orthopaedic surgery, but to give the student a thoughtful approach to the problems of the musculoskeletal system and to medicine in general. It should be mentioned that the allotment of sufficient time does not of itself assure good teaching in orthopaedic surgery. The more efficient the teaching, the less time is needed. The student's time must be well occupied.

DISCUSSION

By Carl E. Badgley, M.D., Ann Arbor, Michigan
University of Michigan

Our program at the University of Michigan is somewhat similar to that which Dr. Green has just outlined.

Constantly throughout the year we have clinical conferences with the Department of Anatomy on embryology, attempting to demonstrate the embryological facts which are brought to light in our clinical material. We similarly have conferences and clinics in the Department of Anatomy, in which we attempt to demonstrate the need of knowledge of anatomy in clinical material. In the second year we have six hours on the pathology of the healing of fractures. Also in that second year, with the Department of Internal Medicine, we have six hours in the teaching of physical diagnosis.

In the third year the class is divided into sections. Each section spends three afternoons a week, for two weeks, in the orthopaedic Out-Patient Clinic. Fractures are taught to each section didactically, two hours a week for four weeks. We believe that these students acquire a fundamental basis of the knowledge of fractures. We have ten orthopaedic lectures. In those ten hours we do not pretend to teach all of orthopaedic surgery, but it is our aim to present a knowledge of such topics as bone growth and bone repair, the normal development of the growing child, and the diseases to which that child can fall heir. We also present those diseases in adults which are peculiar to our specialty. We attempt as much as possible to demonstrate that the work of the Department of Orthopaedic Surgery must be correlated with that of other departments.

In the fourth year, as Dr. Green recommended, we have the senior medical students with us for the entire time for two weeks. During that period of time, they are in the operating room, where they "scrub up" for operations on cases, in the Out-Patient Department, and acting as assistants and clinical clerks in the

wards. Once a week we have a general conference on fractures, which the senior residents attend. This conference is primarily for the Division of Orthopaedic Surgery, which is in charge of fractures. These conferences are also attended by the general surgeons.

I would say that, with few exceptions, we have everything Dr. Green has recommended for the orthopaedic curriculum.

THE RELATIONSHIP OF THE DIVISION OF ORTHOPAEDIC SURGERY WITH THE OTHER DIVISIONS OF SURGERY

By Alan D. Smith, M.D., New York, N. Y.

Columbia University

This morning in his Presidential Address, Dr. Robert I. Harris said most of the things I had thought of saying on this subject, but stated them very much better than I can.

In order to orient ourselves about the position of the department of orthopaedic surgery, we should think of the recent developments of surgery and the fact that there really no longer exists such a department as general surgery. We all have to be surgeons first and specialists afterward. When I was an intern on the surgical service, thirty years ago, we did abdominal and thoracic surgery, and brain surgery; we treated fractures; we practised gynecology and urology; and we were really general surgeons. That is all changed. Technical advances in surgery have been so great that no one now thinks he can master all those techniques, and he has been forced to specialize more or less in one particular field of surgery. By general surgery, I think we mean the fundamental principles of surgery which we all have to master to be surgeons. The idea that it is necessary for men to learn the principles of treatment of shock and water balance, infection, and so on, by going through the department of general surgery (which now is really the department of visceral surgery), is no longer true.

Therefore, I think that the department of orthopaedic surgery should be simply one of the departments of surgery, but a very important one. If you think back, you will see that until a comparatively short time ago, what we now consider as the scope of orthopaedic surgery was almost the entire field of surgery, before abdominal and thoracic surgery came into being. We really cover a great part of the body and treat more types of lesions than any other branch of surgery. I believe that the best plan is to give each department of surgery a large degree of independence, and yet hold these departments together by an organization; otherwise there will be more or less anarchy.

There must be an executive officer of the department. You can call him the professor of surgery, if you like, or he may be the professor of visceral surgery, or the professor of orthopaedic surgery or neurosurgery, but he is the executive officer of the department and the one who binds all the different parts together. It takes a number of qualities to make a good professor of surgery. He has to be a good teacher, a good surgeon, and a good administrator. Very often the departments of surgery suffer because the head of the department is not a good administrator, and I think, therefore, that the man should be selected not as much because of the particular field of surgery in which he happens to be interested, but because of these other qualities that are so necessary in administering the department.

At Columbia University, all the specialties in surgery are independent, but we have, of course, a professor of surgery. I think that is the way it should be done; but the so-called surgical specialties should not necessarily be subordinated always to the so-called department of general surgery. There must be a great deal of cooperation between the various branches of surgery, because even in the cases which we consider to belong to the field of orthopaedic surgery we frequently need the special skill of other men, such as the neurological surgeons and plastic surgeons, and we should feel free to call upon them to help with particular problems.

Also in teaching there is a great opportunity to collect many of these things and present them as a whole, because you cannot separate diseases into compartments. They do not lend themselves to that at all. I think that the plan of holding symposia on tuberculosis, for instance, in which the internist, the orthopaedic surgeon, the pathologist, the bacteriologist, and others cooperate to present that disease as a whole, is an excellent one. That plan could be extended to other diseases, such as poliomyelitis and cerebral palsy.

THE RELATIONSHIP OF THE DIVISION OF ORTHOPAEDIC SURGERY WITH THE OTHER DIVISIONS OF SURGERY

By Donald King, M.D., San Francisco, California

Stanford University

I am afraid that everything I had thought of saying has already been mentioned, and perhaps in a way far better than I could have said it to you. I would like, however, to stress one technical method of teaching

which Alan Smith spoke about. There has never been any radical separation between the various specialties in the Department of Surgery of Stanford Medical School. In fact, one might say that this is also true of the various departments. For example, all members of the staff attend Dr. Bloomfield's Friday morning medical rounds and Dr. Newell's Monday afternoon X-ray Conferences, Dr. Newell being our Professor of Radiology.

During the past two or three years we have been experimenting with a method of teaching which has still further unified the divisions of surgery into a more compact department. This method, which is actually a very old one, is used particularly to present those subjects which are of interest not only to the orthopaedic surgeon, but also to other divisions or departments. We might, for the purpose of illustration, mention the subject of tumors.

A class is conducted jointly by the orthopaedic surgeon, the pathologist, and the roentgenologist. Patients are shown to illustrate the various types of bone tumors, and for the benefit of the students, the three professors participate in the discussion concerning each case.

Other orthopaedic subjects lend themselves very naturally to this method of presentation. I might speak of poliomyelitis, which Dr. Smith has already mentioned. In presenting this subject, Dr. Faber, the Professor of Pediatrics, starts with the presentation of the clinical picture and the acute phases of the disease. He is followed by Dr. Northway, Professor of Physical Medicine, who demonstrates the physiotherapeutic aspects of the subject. Finally, a member of the Orthopaedic Division closes with a presentation of the fundamental principles of the orthopaedic treatment of the disease.

Another subject which is well adapted to this method of presentation is fracture of the spine with damage to the cord, where we are able to have the genito-urinary surgeon, the neurosurgeon, and the orthopaedic surgeon participating in the discussion in front of the students in a round-table type of discussion. It is quite obvious that such a teaching program requires considerable preliminary preparation and a willingness on the part of various teachers to admit that their particular role is not necessarily the stellar one. We've found students to be most enthusiastic about this method of teaching, and I feel that it has resulted in a much warmer interdepartmental relationship than previously existed in our school.

THE USE OF AUDIO-VISUAL AIDS IN TEACHING

By Fremont A. Chandler, M.D., Chicago, Illinois

University of Illinois

The subject of orthopaedic surgery lends itself admirably to the use of visual aids in its presentation to medical students, especially those in the preclinical years of their teaching. Patients are the ideal form of presentation from the visual angle, but they are not always available at the proper time, and some such presentation must be supplemented by other means, such as drawings, charts, models, lantern slides, or motion pictures. The need for such aids is brought out in the study of answers to a questionnaire sent out by Dr. Shands over a year ago. To the question, "Are visual aids, such as lantern slides, motion pictures, models, et cetera, made use of?", seventeen schools replied that they were used extensively, thirty-eight schools replied that their use was moderate, and fifteen replied that they were used only occasionally.

To the question, "Would your department be willing to collaborate on such visual aids for teaching if a central office of exchange were established?", sixty-eight of the seventy schools responded in the affirmative. This is evidence of the need for such means of presenting the subject of orthopaedic surgery to students.

Under the present plan, each medical school attempts to supply these needs through its own departments of art, photography, et cetera. This means that seventy medical schools must have seventy artists, often working on the same problem. Would it not be possible for us to combine our efforts and share the products of our art departments with one another, supplementing the material which each of us has available with the choice and more selected material which our colleagues have encountered elsewhere, by putting all into a common pool? The effort of preparation would be minimized and many valuable presentations would become available to all.

THE USE OF AUDIO-VISUAL AIDS IN TEACHING

By Joseph S. Barr, M.D., Boston, Massachusetts

Harvard University

I should like to make clear at the outset that my remarks represent my personal feelings rather than the attitudes of Harvard University.

The "chalk talk" is the simplest example of audio-visual education. Roentgenograms, dissected specimens, the articulated skeleton, et cetera, may be used as visual material, but such material can be seen

satisfactorily by only a handful of students at one time. To overcome this, as seen in our scientific sessions, the visual image is enlarged by projection from lantern slides or by making a "blown-up" three-dimensional model of the original. I suppose that at present all but a minor fraction of undergraduate or orthopaedic teaching is done with no more complex aids than those just mentioned. Many of us have made motion-picture films of operative procedures of interesting cases, but such films, in my opinion, have little or no place in undergraduate teaching. There does seem to be a place for a few well-made basic films on orthopaedic subjects.

If such films were available, they would improve the general quality of our teaching and give the student a far better concept of orthopaedic disabilities than do our present more or less haphazard lectures.

Under a general title such as "The Locomotor System", the series might include (1) a film on "physical examination", (2) one on "trauma and repair", (3) one on "the aging process", (4) one on "normal and abnormal gaits", and (5) one on "poliomyelitis".

Let us consider how best to teach the essentials of orthopaedic physical diagnosis to a section of second-year medical students. The subject might be introduced in a ten-minute talk, outlining the ground to be covered. The students are then shown a film, which in sound and synchronized, smooth-flowing action demonstrates the principles of inspection, observation of stance, posture, gait, normal ranges of active and passive joint motion, palpation, measurement of leg length, demonstration of atrophy, observation of sensory, reflex, or circulatory change.

The film should take not over thirty minutes to show,—and I wish to emphasize that it is not a lecture, but a tool to be used by the lecturer. When the lights come on, the instructor distributes the syllabus which covers the film content and includes a check sheet for recording physical findings. The instructor then examines a patient in front of the section and the findings are discussed. Each student is given the opportunity of taking a history and doing a complete physical examination on the patient. He writes up his case, records his findings, his tentative diagnosis, and recommendations. This case may be reported as a basis for a grading mark, if the instructor so desires.

This, then, is a brief illustrative outline of my concept of the type of film needed. A film on "trauma and repair" could introduce the subject of fractures in a vivid way.

It is obvious that a number of first-grade teaching films for undergraduate students are needed. I would suggest that a committee be assigned to study the problem and to draw up a list of films and their proposed content.

Financial sponsorship for production of the films might be solicited from the A.O.A., from the Academy, from philanthropic foundations, or from anyone who is interested in giving funds to see that medical students are better taught. After sufficient funds have been secured, a qualified script writer should be employed and scripts should be prepared for approval. Problems of film production and distribution will require careful study.

This appears to be a field in which carefully planned, concerted action is necessary. I suggest that the time for action has arrived.

DISCUSSION

PAUL B. MAGNUSON, M.D., *Veterans Administration, Washington, D. C.* (Formerly of Northwestern University, Chicago): There is being planned, by cooperation among a number of government departments, a central pool of teaching films, and we in the Veterans Administration are prepared now to assign funds for the production of teaching films after the necessary scenario has been submitted and approved. They can't all be made in one year; that would be impossible. However, an extensive program is being planned, and this will include an arrangement whereby those films may be obtained in copy form, either by purchase or loan, by a university or other medical teaching institution.

During World War II, I was called upon to do some teaching which consisted of concentrated courses to be given to Army medical officers in periods of six weeks. Most of this instruction was necessarily centered on anatomy. We did not have an excess of anatomical dissecting material at Northwestern University, so it was necessary to devise ways and means for teaching anatomy so that it would be remembered. To that end we undertook the teaching of what we called "constructive anatomy".

In other words, human bones were put together with plasticine and mounted on an old-fashioned retort stand—a scapula, a clavicle, and a humerus, for instance, in slight abduction—and we modeled the whole arm and the whole lower extremity in that way, the students having their anatomical "aphorism" charts and books in front of them and the dissected material at the other end of a long laboratory.

The students thought it was very simple at first, until they found that they knew nothing at all about anatomy when they looked at the book. They had to walk to the other end of the room to observe the normal anatomical relations, then walk back and reconstruct them; and after about three trips to the other end of the room to see how man was made originally, they began to see the reason for this form of teaching. Those men knew more anatomy at the end of six weeks than they ever had known before.

The instructor could then ask, "If a bullet strikes a man anteriorly and comes out at the medial edge

of the scapula, about halfway between top and bottom, what structures does it interfere with, and how do you make an examination to find out what structures were injured by the bullet?", and expect to get the correct answer.

That method of teaching proves that constructive anatomy impresses the individual with the mechanical aspects of anatomy, but it doesn't correlate with the physiology. However, with these visual aids it seems to me that we can make a much greater impression on these young individuals, whether undergraduates or graduates.

I found that the graduates probably know less about anatomy, as a rule, than the undergraduates. Unless anatomy, physiology, pathology, and embryology are correlated in the minds of these students, they don't remember them very long. And when these subjects can be correlated clinically, the students learn something that they remember.

DON H. O'DONOGHUE, M.D., *University of Oklahoma, Oklahoma City:* All of us who have been interested in teaching orthopaedic surgery have problems which to us seem very acute. I want to speak briefly about one problem which gives us considerable concern.

I think we have all been faced with the problem of lecturing to a group of sophomore or junior students, seventy-five or eighty in number, on the subject of fractures or orthopaedic surgery. Certainly I feel very much concerned as to whether what I am telling the students is at too low a level for them, so that they go to sleep, or at such a high level that they cannot comprehend it.

I think the time has come when these classes should be broken up into smaller groups. We are faced with two things. One of these is that, in the years before World War II and even antedating that, the number of qualified orthopaedic surgeons was few, so that if the school was fortunate enough to have one good teacher, his teaching capacity was used to the utmost. The other is that, during the last War, there was such a scarcity of teaching help in the medical schools that each one who remained at home had to carry his full load and use his time to the best advantage for him and not for the student.

In our department, for instance, we have eight or ten qualified orthopaedic surgeons; all of them are certified by the Board, although some have had more experience than others. Possibly our students, who get some sixteen hours of didactic instruction in fractures during their junior year, would do better to have one teacher for each eight or ten students, even though he did not happen to be the best teacher on the staff. His ability to teach eight or ten men would be better than the ability of the best man of the group to teach eighty students.

We all recognize that it is impossible to cover the whole subject of fractures in any such course. I think we should teach basic things. For instance, if you teach the detail of treatment of fractures about the ankle joint, you have covered in effect the treatment of fractures about any other joint. Similarly, the treatment of fractures of the long bones is essentially the same, whether the bone is the femur, the tibia, the humerus, or the radius.

W. E. GALLIE, M.D., *University of Toronto, Toronto, Canada:* I am glad of this opportunity to take part in this important discussion, because I have had to view the problem from a very different angle from that of the previous speakers. Their viewpoint has been that of the orthopaedic surgeon, the Director of the Orthopaedic Department, and the Professor of Orthopaedic Surgery. Mine, however, has been not only that of the Professor of Orthopaedic Surgery, but also that of the Professor of Surgery, for I have been head of the Department of Surgery, including all the surgical specialties, for the past twenty years.

Most of the speakers have been dissatisfied with the place that orthopaedic surgery occupies in the curriculum and feel that, because of the enormous advance that it has made in the past twenty-five years, it should be given increased time and even complete independence from so-called general surgery.

Before coming to any final conclusion in this matter, I think we should pause for a moment and consider just what should be taught to undergraduates. Is it possible that the great widening of the field of surgery, with its special branches of urological surgery, neurosurgery, orthopaedic surgery, thoracic surgery, and so on, may have other effects on the teaching of surgery than simply increasing the undergraduate curriculum? The answer, of course, is that it has. Within the last ten or fifteen years we have seen the rise of the American College of Surgeons, the Royal College of Surgeons of Canada, the American Boards of Surgery, and of the Surgical Specialties, all of which are committed to the principle that in the future major surgery shall be done only by those who have been properly trained for it. This means about five years of postgraduate work.

If, then, qualification to practise surgery or one of its specialties is going to require prolonged apprenticeship and postgraduate study, what is the object of expanding the undergraduate curriculum? It seems to me that instead of increasing the amount of time allotted to orthopaedic surgery and all the other surgical specialties, and, indeed, to general surgery itself, we should reduce it. If we insist upon more time for the teaching of surgery and its specialties to undergraduates, most of whom are going to be physicians or general practitioners, we are simply perpetuating the present unhappy state of affairs, in which much of the surgery is

done by poorly trained men. We are placing in their hands the opportunity to do things that we know they should not do.

The answer to the question, "What should the department of orthopaedic surgery teach in a medical school?", is threefold.

First, it must take part in the teaching of surgery to the undergraduates. This teaching should be concentrated on anatomy and physiology as applied to surgery, or general and surgical pathology, with special reference to inflammation, infection, healing of wounds and injuries of all kinds, thrombosis and embolism, gangrene, and so on; and, finally, the taking of histories, the making of a good physical examination, and arriving at a diagnosis. You will note that there seems to be no place in this program for teaching orthopaedic surgery. All we are supposed to do is to teach the general principles of medicine and surgery by means of the patients who are gathered together on our wards. To be a successful teacher of undergraduates, the orthopaedic surgeon must forget his specialty for the moment and go back to the fundamental principles that underlie all specialties.

In order that the teaching of surgery may be carried out well, it seems to me that it must be under single direction. To place such a program in the hands of half a dozen separate departments would result in all sorts of confusion and would certainly defeat any plan of teaching general principles. The function of the professor of surgery is to plan the course and to see that it is properly carried out.

The second great job of the department of orthopaedic surgery is to teach the principles and the practice of orthopaedic surgery to the young men who are being trained in general surgery. They will ultimately go out to all parts of the country to take the place of the general practitioners, who at present do most of the surgery. It is my thought that a well-trained general surgeon should have at least a six months' assistant residency in orthopaedic surgery and also a period of concentrated experience in fractures. It is from these young men, who are passing through the department in their training as general surgeons, that promising candidates can be selected for training as orthopaedic specialists.

The third important function of the department is the training of orthopaedic surgeons. This, of course, is the most pleasant and interesting of our teaching duties and is the one upon which we must depend for the advancement of our specialty. Concerning this I cannot suggest anything that you do not know as well as I do. My only comment is that I would not accept a candidate for training as a surgical specialist of any kind who had not had a good basic training in general surgery, and who had not been influenced in his desire for further postgraduate training by his experience in the special department while taking his general surgical training. Such a plan makes certain that the candidate understands fully the nature of the specialty he proposes to learn, and it gives the staff an opportunity to form an opinion, before it is too late, as to whether he has the qualities that are necessary for success in that field.

J. A. Freiberg, M.D., *University of Cincinnati, Cincinnati, Ohio:* This discussion has been very interesting. There is one point that seems evident to me in the expanding of the program proposed for the teaching of orthopaedic surgery to undergraduates.

Why do we, as orthopaedic surgeons, have to teach anatomy? Obviously, because we think anatomy has not been taught correctly. The same reasoning applies to biochemistry and physiology. I think our efforts should be directed in the medical schools to see that the various departments of the fundamental sciences plan their particular subjects in the undergraduate program to cover what we believe should be covered. I say this because of my close relationship with the Dean in my particular Medical School, knowing that great demands are made on him to increase the teaching time in every department in the Medical School. If we were to grant even one-tenth of the increase in time which is asked for by each department, the school could not function on the basis of four years.

We have recently had a professor of anatomy who taught functional anatomy, knowing—and I say this advisedly—as much about joint function as any man in this room. We can't all get such professors of anatomy. Unfortunately, ours died suddenly a month ago. He showed many in our Medical School what can be done, and, therefore, I see no reason why orthopaedic surgeons should have to teach anatomy to freshman medical students. Nor do I see why we should enter into the teaching of physiology of bone and joint function, when others of our medical-school faculty should know, and probably do know, more than we do about it, but do not happen to teach physiology the way we feel it should be taught. Again, our efforts should be directed toward altering and improving the teaching, rather than doing it ourselves.

I do feel that we, as qualified specialists, should give the fundamental training in orthopaedic surgery to the undergraduates. The students cannot get this instruction adequately from any other department in our medical schools. There are two extremes in instructional programs,—expansion of the time for the specialties, and elimination of the teaching of specialties to the undergraduate. I recommend a middle road.

John W. Ghormley, M.D., *Albany Medical College, Albany, New York:* In the teaching of orthopaedic surgery to students, we have to remind ourselves constantly that we are teaching undergraduates and not postgraduates. There is a strong urge to demonstrate unusual cases, especially those which have had excep-

tionally good operative results. There is also a great tendency to discuss new operative procedures, about which the instructor has recently learned and in which he is greatly interested.

Very few students will become orthopaedic specialists. Some will become specialists in other fields; many will go into general practice. We, therefore, give the greatest part of our teaching hours to the demonstration and discussion of cases which can usually be diagnosed by the general practitioner and often treated by him. For example, we would like to have our graduates who are in general practice diagnose osteo-arthritis of a knee by the physical examination and treat the condition by rest, avoidance of extra exertion, especially stairs, reduction of weight, arch supports, possibly a supportive knee bandage, and local heat and massage. We are chagrined when we find that one of our recent graduates is giving these patients vaccines or "shots in the arm", or even twenty minutes of short-wave diathermy.

Our students at present do not spend any time in the operating room, assisting in or observing operations. There are very few didactic lectures. There are assignments in an orthopaedic outline for students, which we have been using for many years, and the students are inspired to study this because they have a weekly written quiz on the assignment. They spend considerable time in the out-patient department and the remainder of their time on the wards. They work up cases which are to come to operation. They may see the operation and they follow the cases postoperatively. They usually present the case to the whole class.

Thus, only a part of the students' time is taken up with a study of hospital diagnostic and operative procedures. Enough time is given to this, however, so that they will know what can be accomplished by such procedures. By this means they will know what cases they can take care of themselves and which ones are better treated by more specialized procedures.

Our theory, then, is that the student should learn general orthopaedic principles so that he can intelligently care for the many orthopaedic problems that he meets in general practice. Let the man who is to become an orthopaedic surgeon get his specialized training in his postgraduate courses.

ARTHUR STEINDLER, M.D., *The Children's Hospital, The University of Iowa, Iowa City:* I have heard with the greatest of profit the discussions on the curriculum for orthopaedic training of undergraduates, especially those given by Dr. Green and Dr. Badgley. I am primarily a teacher of graduates; thirty-five years' experience has taught me the errors and the illusions of teaching, when it is not founded upon the very sane and safe principles postulated here.

However, I am discouraged and not satisfied with the situation and the discussion as it has developed so far. It is taken for granted that, if the opportunities are given, that is all that is necessary. The reader must have the introspection, the urge, and the didactic abilities to dispose of a subject in its whole form. I can't conceive of a presentation of a subject that is not in itself a whole; it must refer constantly to the basic foundations and not depend upon basic sciences presented separately.

I believe it is a mistake to think that you can begin where the other departments have left off,—that you need not imbricate and dovetail with the basic sciences. If you hold to strictly specialistic presentation of the subject, where is the assurance that you are not going to separate the student from the common ground of medicine?

The first prerequisite in graduate training seems to me that the student must never be allowed to lose contact with general medicine. I have no trouble making specialists out of my graduates, but I have a hard time making doctors out of specialists.

PAUL C. COLONNA, M.D., *University of Pennsylvania, Philadelphia:* From the many ideas brought forth in the discussion, it is clear that the teachers in the various medical schools throughout the country are aware of the need for improvement in the teaching of orthopaedic surgery during the formative years of the medical student. Incidentally, I am glad to note that we are getting away from the term orthopaedics and designating our specialty as orthopaedic surgery.

Our instruction in the past has largely been devoted to the graduate and postgraduate student, but if we wish to raise the quality of young men going into this specialty we should begin by interesting the medical student in this subject.

Many excellent suggestions have been made this afternoon and I have been particularly impressed with three approaches to this problem: first, to have a few orientation lectures during the first two years and didactic and bedside teaching in the third and fourth years; second, the symposium method of teaching, in which the different departments of the preclinical and clinical divisions of the medical school can take part, so that the student obtains a broad view of the particular problem discussed and understands the usefulness of careful history-taking, examination, and differential diagnosis; third, the almost untapped field of utilizing audio-visual aids in teaching.

It is, of course, recognized that the most important factor in this or any other subject is a stimulating teacher, who has the ability to arouse scientific curiosity in the group to which he is speaking, whether it be with small groups in bedside teaching or with larger groups.

PROFESSOR GEORGE PERKINS, *St. Thomas Hospital, London, England:* Orthopaedic surgery can be considered either as a specialized branch of surgery or as a small section of medicine that typifies the whole of medicine. If orthopaedic surgery is to be considered as a specialized branch of surgery, we must consider how many hours the average student should devote to that specialty.

The crucial fact that most students are eventually to become general practitioners is often overlooked. In this age of specialization, we are inclined to forget that the prime aim of a medical school is to produce what laymen call doctors. We have first of all to make this student a doctor.

Medical knowledge is like our national debt. It is always on the increase. Year by year, the mass of knowledge accumulates and specialists become more numerous. Every specialist demands that the students should spend an undue proportion of their time in his own specialty. It always amuses me to ask a specialist how many lectures he thinks should be given in his subject. The anaesthetist wants twelve, the endocrinologist wants twelve, the gynecologist wants twelve, and the psychologist may want twenty-four. If all these men were given what they demand, the student would be attending lectures all day long, and he would have no time for examining a patient or, which is more important, for talking to a patient, let alone time in which to sit and think.

It seems reasonable that the amount of time devoted to any subject should be related to its frequency in the ordinary general rounds of a practitioner. Based on this premise, orthopaedic surgery is one of the major specialties, because patients with complaints like flat feet, lumbago, and the like, form a large proportion of a general practitioner's practice. However, the claimants on a student's time are so numerous that the orthopaedic surgeon must moderate his demands. In my school the authorities allot six lectures a year to orthopaedic surgery. It will always be impossible to cover the whole of orthopaedic surgery in six lectures.

What then ought the lecturer to deal with,—subjects of interest to himself, such as bone tumors and arthroplasty of the hip, or subjects which are going to be of use to the general practitioner afterward, such as metatarsalgia? As the general practitioner may see a hundred cases of metatarsalgia to one bone tumor, obviously metatarsalgia should have the preference. I think the orthopaedic surgeon has to reconcile himself to giving only a very few lectures and those on dull subjects, if orthopaedic surgery is to be considered as a special department of surgery.

In my Hospital, what we call the apprentice system prevails. The student spends six months as an in-patient surgical dresser, during which he spends most of the day in the wards, where he learns surgery from one so-called general surgeon. He spends another six months in medical wards, learning medicine from one general physician. For the rest of his tutelage he is free to go on ward rounds, attend out-patient clinics, or visit special departments. During that period he is not attached to any particular man. The result is that the student gets to know intimately only the physician or surgeon to whom he is apprenticed, and he gets the impression that the medicine and surgery which are practised in special departments are of no moment.

Let us consider the other method of looking at orthopaedic surgery,—namely, as a small section of medicine that illustrates and typifies the whole of medicine. This, I think, should be its role in an undergraduate medical school.

The orthopaedic surgeon can, by reference to his own specialty, teach almost all the principles of medicine. He can show examples of inflammation, degeneration, disordered growth, new growth, repair, disordered nervous activity, endocrine disturbance, and faulty nutrition. These are examples which are visible; the pathological processes can be seen and felt. In fact, only the dermatologist has a better opportunity for teaching the principles of medicine. Moreover, when the orthopaedic surgeon operates upon a patient, he is able to judge the results of his treatment. It does no good for him to try to gloss over his failures because his patient will not let him. As a consequence, the orthopaedic surgeon is much more inclined to hesitate and to ask himself: "If I do this to my patient, shall I benefit him or shall I do him harm?"

How much time should be allotted to orthopaedic surgery? This depends not only upon the intrinsic importance of the specialty, but upon the teaching ability of the surgeon in charge. I can conceive of an orthopaedic department having at its head an extraordinarily fine technician who is a poor teacher. If I were the dean in that school, I would allow the students to pay only a cursory visit to the orthopaedic department. On the other hand, I can conceive of the orthopaedic surgeon, besides being a brilliant technician, being an inspired teacher. I can conceive of that much more easily because I had the good fortune to be brought up and taught by a very famous teacher, the late Mr. Rowley Bristow. If I were dean, I would send students as often as possible to the orthopaedic department which had a man like Mr. Bristow at its head. The difficulty is that the dean cannot be constantly changing the student's curriculum.

When the student goes into the wards for his in-patient dressing, I would not allow him to spend the whole of that time with one man, but make him rotate so that he would see half a dozen different types of surgeons. Sitting in succession at the feet of different surgeons would disabuse his mind of the idea that surgery can be learned only from the general surgeon. With this system the student would learn his surgery and develop his surgical mind from the man who taught best, whether that surgeon be an abdominal surgeon, a plastic surgeon, an orthopaedic surgeon, or any other kind of surgeon.

I believe the orthopaedic surgeon should teach general principles of medicine. For example, he might take three such conditions as hyperthyroidism, peptic ulcer, and perhaps synovitis of the knee as constituting a

similar problem of what to do if an organ of the body secretes more than is needed, because the principle of treatment is the same. You either diminish the amount of secretion or neutralize it, or you take away part of the organ that is secreting it.

Finally, concerning how the surgeon should teach, I believe the more dogmatic the teacher is, the better is the teaching. However, the teacher should mitigate the effects of his dogmatism by instilling skepticism into the minds of the students.

F. H. Arestad, M.D., *Council on Medical Education and Hospitals, American Medical Association, Chicago, Illinois:* First, let me express to this Committee the appreciation of the Council in having an opportunity to participate in this meeting.

The Council, as you know, is primarily concerned with medical education, both at the undergraduate and the graduate levels. Of course, we are deeply interested in the opinions and the experiences of this group, and the planning of effective teaching in the field of orthopaedic surgery. This is a particularly opportune moment for a meeting of this type in relation to the work of the Council, because we will begin very shortly to conduct another major survey of medical education in the United States, similar to the program that was carried out in 1934 to 1935 by Dr. Weiskotten, who at the present time is Chairman of the Council. From this discussion and the presentation of papers this afternoon, I assume that the major objective is to develop a model plan that can be used as a guide to orthopaedic departments in the various schools throughout the country.

I think we should keep in mind that while a guide is useful, it should not be developed as a fully standardized plan, because you can never really standardize teaching itself. It can be useful, I am sure, in developing some suggested methods, particularly an earlier introduction of students to an understanding of orthopaedic surgery as a whole, so that they may be able to comprehend more readily what is involved when, in their third and fourth years, they come into actual contact with orthopaedic problems. I was particularly impressed with one of the objectives that was stated by one of the discussors, who said that the plan of teaching should also serve to stimulate the student. This inspirational teaching comes from the men who, by special qualities, interest, and enthusiasm, are able to stimulate their students.

I believe the meeting has also shown the need for further conferences of this type, as many different views have been expressed that will need further consideration in times to come.

I should like to read a statement which I brought with me that may express in some measure the views of our office; you will sense, as I read this, that we are thinking primarily in terms of practical education, less in terms of didactic instruction:

"Medical directors and medical educators as a group believe that in the teaching of the surgical specialties, stress should be placed primarily on the basic principles of pathology, physiology, diagnosis, and therapy rather than on techniques and details. As much as possible, instruction should be correlated with instruction in general medicine and surgery and with the preclinical sciences.

"It is generally recognized that there is not time in the undergraduate course to train students in the techniques of the various surgical specialties. Adequate training in surgical technique can be acquired only during the internship and residency years. Therefore, it is recommended that in the undergraduate teaching of the surgical specialties, expositions and discussions of technical procedures be reduced to the minimum that is necessary for an understanding of the principles of therapy. With the elimination of detailed instruction in surgical techniques, there has been in the past twenty years a general reduction in the number of hours assigned to the various surgical specialties in the undergraduate curriculum.

"In the surgical specialties, as in all other clinical subjects, the course of instruction should be built primarily around work with patients with a minimum of straight didactic instruction. Whenever possible, the student should be given the opportunity to work individually under supervision in the out-patient department or on the hospital wards."

There is one other point that I should like to raise as a question of approach. It was mentioned today, I believe by Dr. Green, that orthopaedics ought to have 20 to 25 per cent. of the time devoted to surgery. I am just wondering if that is the right approach to the problem, although it is a good statement to be brought before a conference of this type because all of you have an opportunity to carry these thoughts and discussions back to your schools.

The reason I'm questioning the approach is that it implies you are going to take something away from surgery or from some other specialty. Actually, surgery will need whatever time is required to do its work; so will all the other specialties in medicine. The time element should be considered from the standpoint of the entire curriculum, as any additional time that is needed might come from obstetrics, from internal medicine, from psychiatry, from surgery, or from some other field, but would not necessarily be a reduction of general surgical training in order to give orthopaedic surgery an additional amount.

I believe also that Dr. Green brought out an important point, mentioning that time itself is not always the most important factor. Rather it is the effective utilization of time, and therein lies that quality of teaching which enables instructors to present a subject with interest and with the greatest val e to students.

SUMMARY

By A. Bruce Gill, M.D.

At first glance it might appear that the opinions expressed by the speakers who have participated in this symposium are very diverse and even, at times, irreconcilable; but a careful study of them reveals that there are fundamental points on which many of the speakers agree.

1. The majority of medical students will become general practitioners. The student's undergraduate training and his subsequent experience as an intern in a hospital must fit him to enter upon his practice. If he has not had good basic training in the medical school, he will be greatly handicapped during his internship. When he has completed his internship, he has not been trained as a specialist. The general practitioner will be called upon to examine and to treat all sorts of diseases and injuries, and at times to refer a patient to the proper specialist, if one is available. Undergraduate teaching must, therefore, include the basic principles of the specialties, but should be limited to the fundamental things which every "doctor" should know.

It might be mentioned that the teaching of the basic sciences should be subject to the same limitation. The medical school should not graduate specialists in anatomy, physiology, pathology, biochemistry, or bacteriology. The question may well be asked whether in medical schools too much time and too much emphasis is given to one or more of these basic sciences. Should it be essentially a school for pure science or a school of applied science? If the latter, then the application of the pure sciences to the practice of medicine should go hand in hand with the teaching of the basic sciences. For example, descriptive anatomy and functional anatomy should be taught together. If an orthopaedic surgeon should be called upon to assist in the anatomical department in teaching body mechanics and its application in surgery, no more time would be required than is at present allotted in the curriculum. In fact, time could be saved and the students would receive more interesting and profitable teaching.

2. Orthopaedic surgery is a large and important branch of surgery as a whole. The teaching of the basic facts and principles of the surgery of the musculoskeletal system can be done better by an orthopaedic surgeon than by a visceral surgeon. Inasmuch as the fundamental principles of surgery are applicable to all parts of the body, the orthopaedic surgeon is participating in the teaching of surgery as a whole and is demonstrating the application of the basic sciences and of medical and surgical principles in his own particular field of surgery. Furthermore, the opportunity of teaching methods of complete and accurate examination are unexcelled in any other branch of surgery. As emphasized by many of the speakers, the orthopaedic surgeon should not be teaching his students to become specialists, but he should be given the opportunity in the curriculum to do the things which have been mentioned and which he is pre-eminently fitted to do. This means that the ability and the service of the orthopaedic surgeon should be utilized much more commonly than they are at present in many of our medical schools.

3. An intimate and unselfish cooperation of all departments of surgery is essential to the best teaching. If one administrative officer should head the entire department of surgery, he should be as broadminded and have as wide a vision as Dr. Gallie. The chiefs of all departments of surgery should meet in conference, whether or not there is one administrative head, to determine what and how and by whom surgery should be presented to the students.

My own observation over a period of many years has been that too often in our medical schools the various departments of teaching have, from the very circumstances of their inception and development, pursued each its own independent way, with lack of cooperation and even with jealousy and conflict among themselves.

There should be a unity in the teaching of medicine, each part contributing its quota to the unified whole. What that whole should be cannot be determined by any one man or by a small dictatorial group of men. It must be attained by free and rational discussions by the heads of all the various departments of teaching.

4. There is no difference in opinion as to the value of the use of audio-visual methods in teaching. The remarks of Dr. Chandler and Dr. Barr deserve full consideration. Means should be taken whereby audio-visual aids may be available in all of our schools of medicine.

Note: The Committee regret that, because of restrictions of space, it has been necessary to omit the discussions prepared by the following men: Lenox D. Baker, M.D., Durham, North Carolina; Philip Lewin, M.D., Chicago, Illinois; Paul B. Steele, M.D., Pittsburgh, Pennsylvania; and Peter B. Wright, M.D., Atlanta, Georgia.

News Notes

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Sixteenth Annual Meeting of The American Academy of Orthopaedic Surgeons will be held at the Palmer House, Chicago, January 22 to 27, 1949, under the presidency of Dr. Myron O. Henry.

Registration will begin at nine o'clock Saturday morning, January 22. Scientific and technical exhibits will be ready for inspection at that time. During the afternoon, the Audio-Visual Program will be presented under the chairmanship of Dr. Charles N. Pease; this program will be continued on Sunday morning from nine to twelve o'clock.

The Instructional Courses will begin at two o'clock Sunday afternoon and continue until noon on Monday. A good variety of courses will be offered by a distinguished faculty.

On Monday evening, the Instructional Course dinner will be given, followed by an "Information Please" program similar to the one presented last year; at that time interesting cases will be presented to "stump the experts".

On Monday afternoon, the first session of the Academy will be held, and the new members will be presented with their certificates. Dr. Henry will give his Presidential Address, which will be followed by the first Executive Session.

Tuesday morning and afternoon, Wednesday morning and afternoon, and Thursday until noon will be occupied by an excellent Scientific Program, which has been arranged by the Program Committee under the chairmanship of Dr. Lenox D. Baker. The second Executive Session will be held at noon on Thursday.

The annual banquet of the Academy will be held on Wednesday evening. Alumni dinners and other special groups will meet this year on Tuesday night, rather than on Monday night as in the past.

THE AMERICAN SOCIETY FOR SURGERY OF THE HAND

The American Society for Surgery of the Hand will hold its Fourth Annual Meeting in Chicago on January 21 and 22, 1949. The clinical program follows:

FRIDAY, JANUARY 21

9:30 A. M.

Primary Nerve and Tendon Repair. By Joseph L. Posch, M.D., Detroit, Michigan (by invitation)

Primary Tenorrhaphy. By Vinton E. Siler, M.D., Cincinnati, Ohio

Treatment of Severed Flexor Tendons in the Flexor Sheaths of the Fingers. By R. Sterling Mueller, M.D., New York, N. Y.

Acute Suppurative Tenosynovitis of the Hand. By J. Edward Flynn, M.D., Boston, Massachusetts

Median-Nerve Neuritis. By George S. Phalen, M.D., Cleveland, Ohio

2:00 P. M.

Plastic Repair of the Cleft between the Thumb and Index Finger. By Gilbert L. Hyroop, Lieutenant Colonel, M.C., Valley Forge General Hospital

Thumb Web Contracture. By L. D. Howard, Jr., M.D., San Francisco, California

Adduction Contracture of the Thumb. By William Littler, M.D., New York, N. Y.

Arthroplasty for Ankylosis of the Metacarpophalangeal Joint. By F. L. Liebolt, M.D., New York, N. Y. (by invitation)

Dupuytren's Contracture. By J. M. Bruner, M.D., Des Moines, Iowa

SATURDAY, JANUARY 22

9:30 A. M.

Skeletal Reconstruction in the Hand. By William Metcalf, M.D., Hines, Illinois

Relationship of Superficial and Deep Reconstructive Surgery of the Hand. By W. Brandon Macomber, M.D., Albany, New York

Xanthoma of the Hand. By Thomas W. Stevenson, M.D., New York, N. Y.

Presentation of Cases. By Sumner L. Koch, M.D., Michael L. Mason, M.D., and Harvey S. Allen, M.D., Chicago, Illinois

The clinical meetings will be held at Thorne Hall, Northwestern University, 940 Lake Shore Drive.

On Friday evening at six-thirty, there will be a dinner for members at the University Club, 76 East Monroe Street. A business meeting will follow the dinner.

The Western Orthopaedic Association, under the presidency of Harold E. Crowe, M.D., will hold its next Annual Meeting on October 19, 20, and 21, at the Biltmore Hotel, Santa Barbara, California.

The **Sociedad Latino-Americana de Ortopedia y Traumatología** has recently been organized. Its membership includes surgeons engaged in this specialty in Argentina, Brazil, Chile, Columbia, Cuba, Mexico, Peru, Uruguay, and Venezuela. The first meeting of the new organization was held at Acapulco, Mexico, on July 25. Dr. Juan Farill of Mexico City was elected President, and Dr. José Luis Bado, Secretary General.

The first congress of the Society will be held in Habana in 1950, under the presidency of Dr. Alberto Inclán.

The **New Jersey Orthopaedic Society** held its Third Annual Meeting in Paterson on October 9. The officers elected were: Harold W. Smith, M.D., President; Nicholas Ransohoff, M.D., Vice-President; R. R. Goldenberg, M.D., Secretary; and Roy R. Ciccone, M.D., Treasurer. The following scientific program was presented:

Osteomyelitis of the Spine. By Sidney Brooks, M.D.
Eosinophilic Granuloma. By Vincent Giudice, M.D.
Bone Tumors. By R. R. Goldenberg, M.D.
Treatment of Traumatic Amputation of the Fingers. By Roy R. Ciccone, M.D.
Bilateral Rupture of Quadriceps Muscles. By Eugene L. Wild, M.D.
Capsulectomy for Flexion Contracture of the Elbow. By J. C. Warburton, M.D.
Avulsion of Distal Biceps Brachii Tendon. By R. R. Goldenberg, M.D.

The National Foundation for Infantile Paralysis, Inc., is offering a series of postgraduate fellowships: (1) research fellowships in virology, orthopaedic surgery, pediatrics, epidemiology, and neurology; (2) clinical fellowships in physical medicine; and (3) fellowships in public health. Further information may be obtained from the National Foundation, 120 Broadway, New York 5, N. Y. Application may be made at any time during the year.

HULETT JUDSON WYCKOFF

1889–1948

Hulett Judson Wyckoff was born in Arkansas City, Kansas, but moved with his family to Bellingham, Washington, when he was one year of age. He attended the public schools in Bellingham and then the University of Washington for three years, studying to be an engineer. He entered Northwestern University School of Medicine, graduating in 1916. Following his internship at Cook County Hospital in Chicago, he spent a period of training under Dr. John L. Porter, devoted to orthopaedic surgery; then he served overseas in England and France with the American Expeditionary Forces during World War I. After the War he started practice in Seattle as an orthopaedic surgeon and took over the practice of Dr. Fred J. Fassett, who was the first orthopaedic surgeon in Seattle.

Dr. Wyckoff served on the staff of the Children's Orthopaedic Hospital for twenty-eight years and acted as Chief of Staff for a number of years. He was on the active visiting staff of the old Seattle City Hospital for many years, and likewise was the orthopaedic surgeon for Firland Sanatorium during a long period. He was always most generous in giving his services and never allowed his private practice to interfere with his hospital work for children.

He was a member of many local, national, and international medical societies, including the King County and Washington State Medical Societies, The American Medical Association, the North Pacific Orthopaedic Society, The American Orthopaedic Association, the International Orthopaedic Society, and the Academy of Cerebral Palsy, as well as a fellow of The American College of Surgeons and of The American Academy of Orthopaedic Surgeons. He was a trustee of the National Society for Crippled Children and Adults, and also of The National Foundation for Infantile Paralysis, Inc.

In recent years he had devoted a great deal of time and energy to the furtherance of care for the spastic child and adult. He was instrumental in the establishment of special schools for spastic children under the State Public School system, where the spastic child could receive both physical therapy and special instruction by trained personnel in day schools. The McRay Memorial Hospital for the management of more severe cases was also organized under his supervision.

Dr. Wyckoff had planned to attend the meeting of the recently organized International Orthopaedic Society in Amsterdam during the summer of 1948, but was unable to go, because of his failing health.

Those who did not know him well thought him austere, but his friends knew him as a generous, extremely kind person, with a fine sense of humor. His passing is a great loss to the community as well as to his many friends.

Book Reviews

HANDBOOK OF ORTHOPAEDIC SURGERY. Ed. 3. Alfred Rives Shands, Jr., B.A., M.D. St. Louis, The C. V. Mosby Company, 1948. $6.00.

The third edition of this Handbook was made necessary by the increased demand for its use as a textbook in the teaching of both graduate and undergraduate groups. It is being used as a concise orthopaedic reference by general practitioners, physical therapists, occupational therapists, and in schools of nursing.

In this revision some new sections have been added,—such as those devoted to Osteoid Osteoma, The Treatment of Massive Defects of the Long Bones, the "Adult Round Back", and Injuries of the Lumbar Intervertebral Disks. Certain changes have been made, as in the terminology used in the section on Chronic Arthritis; and the Bibliography has been brought up to date.

The preface to the first edition concluded with these words: "It is hoped that this short textbook will assist in the teaching of orthopaedic surgery, and that it may find a permanent place of usefulness in this special field of medicine". That Dr. Shands's hope has been fulfilled is proved by the need for this third edition. Dr. Richard Beverly Raney collaborated with Dr. Shands in the preparation of this revision.

CHIRURGIE MODERNE DE LA HANCHE. APPORT DE LA RADIOGRAPHIE DE PROFIL (Modern Surgery of the Hip). René Charry. Paris, G. Doin et Cie, 1948. 1340 francs.

This book, built about roentgenographic studies of the hip, also concerns surgical procedures for degenerative arthritis of the hip. The first portion contains a discussion of the lateral roentgenogram of the hip, which is taken diagonally through the groin. The x-ray tube is placed on the medial side of the opposite knee and the x-ray plate is on the lateral aspect of the hip and ilium that are being studied. Excellent lateral roentgenograms are taken in this manner. The profile is modified slightly by external and internal rotation of the hip. Lateral roentgenograms of various pathological conditions are shown.

From this the author proceeds to a discussion, with illustrations, of primary and secondary arthritis deformans. Primary arthritis deformans follows malformation of the hip anteriorly, and there is always overgrowth posteriorly at the line of the joint. Secondary arthritis deformans always follows distortion between the acetabulum and the femoral head. In treating primary arthritis deformans, forage and arthroplastic resection are the procedures commonly utilized. In secondary arthritis deformans, more extensive procedures may be required. Osteotomy or a shelf operation may precede arthroplasty. Forage and neurectomy are advocated for the relief of pain. In contracture of the adductors, a more nearly normal pull is regained by subtrochanteric osteotomy and abduction of the lower fragment. This same procedure, at times combined with downward displacement of the trochanter, is advocated for old irreducible, congenital dislocation of the hip. Similar methods are advocated for pathological dislocation of the hip following osteomyelitis.

The book gives a good résumé of the present-day surgical procedures employed in France for the treatment of disabilities about the hip. It is illustrated profusely with roentgenograms and sketches of the procedures advocated. One would like to see a more complete bibliography.

PREOPERATIVE AND POSTOPERATIVE CARE OF SURGICAL PATIENTS. Hugh C. Ilgenfritz, A.B., M.D., F.A.C.S. St. Louis, C. V. Mosby Company, 1948. $10.00.

This is an excellent book. As the title implies, its primary purpose is to depict the care of the patient before and after operation; but it does a great deal more than that. Every aspect of the surgical patient from electrolytic balance to phlebitis is discussed from a physiological point of view, and measures to prevent complications are outlined.

The first sixteen chapters discuss such subjects as fluid and electrolytic balance, metabolism and nutrition, sedative medication, general preoperative measures, shock, transfusions, deficiency states, organic disease, and chemotherapy. Each of these is introduced by a consideration of the physiological and physiopathological alterations that must be dealt with. When there are alternative or conflicting theories, all are mentioned and the author indicates the reasons for his preference.

The last nine chapters deal with postoperative complications of surgery on the various organs, including the chest, stomach, small intestines, large bowel, biliary tract, thyroid, extremities, and genito-urinary system.

Recommendations for the care of complications are specific and clearly written. The reviewer is unable to think of an untoward incident in a patient's surgical course that is not only warned against, but for which

preventive as well as therapeutic methods are depicted. In addition, the reader obtains a sound and modern knowledge of the physiological processes involved. References are numerous and up to date.

This book is to be highly recommended to anyone whose interest lies in surgery, whether he be a student or an expert in his field.

THE RADIOLOGY OF BONES AND JOINTS. Ed. 4. James F. Brailsford, M.D., Ph.D., F.R.C.P., F.I.C.S. London, J. and A. Churchill, Ltd., 63 shillings; Baltimore, Williams and Wilkins Company, 1948. $15.00.

The new edition of this well-known work is made necessary by the additional facts gleaned from the author's own experience and from the world's literature since the 1944 edition was prepared. The important place of x-ray evidence in the differential diagnosis of pathological conditions presenting similar clinical signs is generally accepted, but each year's study adds knowledge and better understanding of the patterns of the bone disease disclosed in the roentgenogram.

One important addition is described by the author in his Preface: "To assist in demonstrating the various lesions recorded, more than 200 other radiographs have been chosen. In some cases serial radiographs from normality to restitution or disintegration have been used to show the changes in appearances throughout, for these time-tables of changes have an important bearing on the diagnosis and treatment."

In compiling the book, the author has drawn from his own rich experience and from his complete case records, which have been preserved intact throughout two world wars. The result is a clear delineation of the fine points in the diagnosis and study of all types of bone lesions, leading to a better understanding of the disease processes.

The carefully prepared index, which includes references to figure numbers as well as to the text, makes the work of great value as a reference; and the extended bibliography facilitates further study of any special subject.

The book is more attractive than the third edition, in which the illustrations were grouped at intervals throughout the volume, due probably to the fact that during the war years fine coated paper was not available for the text pages. The excellent illustrations in this new edition, placed with their context, not only add to the appearance of the book, but also make it of much greater value to the reader. This is an unusually attractive volume, well printed, profusely illustrated, and carefully planned as to layout,—a superb example of the printer's art as applied to fine medical writing.

TREATMENT BY MANIPULATION IN GENERAL AND CONSULTING PRACTICE. Ed. 5. A. G. Timbrell Fisher, M.C., M.B., Ch.B., F.R.C.S. (Eng.). London, H. K. Lewis and Company, Ltd.; New York, Paul B. Hoeber, Inc., 1948. $5.00.

This is the fifth edition of *Manipulative Surgery* by this author. In it he has again stressed the value of skilled manipulation (under anaesthesia usually) in treating the disabilities of "chronic rheumatic diseases". He has not satisfactorily defined the "what and when" of those diseases for which manipulation is best suited. However, he explains clearly the anatomy, pathology, and prevention of adhesions in and around joints, to which he ascribes nearly all of the clinical signs and symptoms. A chapter on diagnosis of adhesions is brief, but too general for practical use by one unfamiliar with these clinically. Actual procedures of manipulation are described for all the major articulations, including the spine and sacro-iliac joint.

The author is more enthusiastic over the results of this type of treatment than most American physicians. However, he has once again overridden the two traditional objections to manipulation. The first tradition is the fear of increased pain and stiffness; the second is the continued use of routine physical therapy, including re-educational exercises, long after improvement has ceased. He does lay great importance on the use of intelligent physical therapy in the prevention of adhesions and in the after-treatment of cases having had manipulation. He has also written one chapter to differentiate manipulation from osteopathy.

On the whole, the book is well illustrated and contains much worthwhile information for all physicians who treat this type of patient.

OS MEIOS DE DIAGNÓSTICO DA TUBERCULOSE OSTEOARTICULAR (Methods of Diagnosis of Osteo-Articular Tuberculosis). Dr. Dagmar Aderaldo Chaves. Rio de Janeiro, Rodrigues y Cia, 1947.

This study of the diagnostic measures in osteo-articular tuberculosis is the outgrowth of experience on the orthopaedic and children's surgical services, particularly in the *Hospital Jesus*. Some of the material was presented at the Third Inter-American Surgical Congress in Montevideo. The author discusses fully the clinical, roentgenographic, and laboratory aids in diagnosis. Helpful personal comments about the various procedures and a useful résumé are included at the end of each chapter. No new points are brought out in the sections on the clinical and roentgenographic diagnosis.

The author states truly that a diagnosis of tuberculosis can be suspected, but not established definitely by either physical or roentgenographic examination. In his discussion of the course of osteo-articular tuber-

culosis, the author holds to the European teaching of the three periods of Ranke. Gastric lavage and biopsy of lymph nodes are done more frequently in South American clinics than in the United States; biopsy of articular tissue is also discussed. Culture of the tubercle bacillus is still attended with considerable difficulty. Inoculation of material intraperitoneally into a guinea pig has proved a practical method of diagnosis. Differential diagnosis and the pathological anatomy are discussed in detail and many illustrations are shown. A most useful adjunct is the addition of thirty-one case histories with photographs. An extensive bibliography is added.

This is a well-conceived and executed piece of work. The arrangement of the material is very good for teaching. The photographs are clear and well chosen. It should prove a helpful aid in the diagnosis and treatment of osteo-articular tuberculosis.

ESSENTIALS OF PATHOLOGY. Ed. 3. Lawrence W. Smith, M.D., F.C.A.P., and Edwin S. Gault, M.D., F.C.A.P. Philadelphia, The Blakiston Company, 1948. $12.00.

This book is intended primarily for teaching, not from a theoretical, but from a clinical, point of view. Each subject is discussed briefly and then case histories are presented, containing both clinical and pathological findings, and illustrated by photomicrographs. Theoretical data are included as needed to give the complete picture, but the disease is presented primarily as it affects an actual patient. In addition, a selected bibliography is included for each chapter. In their Preface, the authors state that they have tried to save the student's time by preparing a textbook which is as practical as possible, emphasizing the things which they consider fundamental and essential.

This edition represents a considerable revision of the material in the first two editions. New text matter and illustrations have been added, including a few color plates; and the case histories have been condensed. Considerable emphasis has been laid upon parasitic infestations and upon a study of tumors.

The book is divided into two sections, "General Pathology" and "Systemic Pathology", the first portion dealing with such broad classifications as disturbances of circulation and inflammation, and the second with the diseases of the various systems. The illustrations are profuse and excellent; those in the chapter on oncology may be given particular mention. Although photomicrographs are used most frequently, gross pathological specimens and roentgenograms of disease processes are also illustrated.

In general, the book represents an excellent piece of work and should be of great value for teaching or reference.

RECENT ADVANCES IN ANAESTHESIA AND ANALGESIA (INCLUDING OXYGEN THERAPY). Ed. 6. C. Langton Hewer, M.B., B.S. (Lond.), M.R.C.P. (Lond.), D.A. (Eng.). London, J. and A. Churchill, 21 shillings; Philadelphia, The Blakiston Company, 1948. $6.00.

This is the sixth edition of a work which has become a standard text in the literature of anaesthesiology. The arrangement of the book has not been altered. The subject matter includes sections on the physiological and pharmacological information which is fundamental in the practice of anaesthesiology; and on the agents at present available, with description of the techniques of their application in general and special surgery. A chapter dealing with the use of curare and other muscle relaxants has been added, and fresh information upon many subjects has been included.

The author has succeeded admirably in presenting a complete summary of present-day trends in anaesthesiology while still keeping his book a convenient length. The comprehensive bibliography is of great value to anyone who desires more exhaustive information upon the subjects mentioned.

The book would be a useful addition to medical-school libraries, and to surgeons, medical students, and anaesthesiologists.

TREATISE ON SURGICAL INFECTIONS. Frank Lamont Meleney, M.D. New York, Oxford University Press, 1948. $12.00.

This volume is an encyclopedia of all that relates to surgical infections. The book deals with every phase of prevention of surgical infections, their nature, how to recognize them, and all the surgical, chemotherapeutic, and antibiotic methods of dealing with them. There are also very clear expositions of how bacteria enter and spread through the body, and what the body defenses are.

The author is one of the foremost clinical bacteriologists of the present day, as well as a prominent surgeon. The work has been in the process of compilation for a long time, as witness the foreword written by Hans Zinsser in 1940. It has profited by the long interval almost certainly, by reason of being able to present an authoritative treatise on the uses and abuses of antibiotics and chemotherapy.

Illustrative of description of bacterial behavior and of various forms of therapy are many clinical case reports which add greatly to the reader's comprehension.

This book is a classic, and should be in every surgical reference library.

HEMOSTATIC AGENTS. WITH PARTICULAR REFERENCE TO THROMBIN, FIBRINOGEN AND ABSORBABLE CELLULOSE. Walter H. Seegers, M.S., Ph.D., and Edward A. Sharp, M.D., Sc.D. Springfield, Illinois, Charles C. Thomas, 1948. $4.75.

The authors have condensed into ninety-six small pages the recent work on their subject; salient points in the 370 references they cite have been summarized into two hours of easy reading. The outstanding contributions of the writers in the purification of bovine thrombin, and their demonstration of its clinical utility and safety, as well as the major role of the second author in the studies on absorbable or oxidized cellulose, have given them a first-hand knowledge of their field. However, they have not attempted to make us all experts by this volume, but have confined their remarks chiefly to those phases of the subject of use to surgeons.

Their first chapter on the current concepts of clotting mechanisms is a model of lucid presentation of a complex subject. Although they do not themselves point out the clinical applications of some of the data they give, one notes that "the higher the temperature below 50° C., the more rapidly a fibrin clot forms" and that "heat inactivation of thrombin begins at about 40° C." From these two facts one is reminded that the use of heat a little above 40 degrees centigrade is still a worthwhile adjuvant to the placement of gelatin sponge or oxidized cellulose soaked in thrombin for hemostasis. Again they point out that plasma contains so much antithrombin that a given amount of plasma, when standing mixed with an excess of thrombin, will destroy ten times as much as the total potential thrombin yield from the same amount of plasma. Hence, at operation, one should not contaminate the stock supply of thrombin by returning blood-soaked pieces of sponge or cellulose to it.

Of special interest to orthopaedic surgeons are these facts: (1) Thrombin as the dry powder may be rubbed into bleeding bone surfaces with prompt arrest of hemorrhage. (2) Oxidized cellulose slows the reparative processes in bone fractures, and hence should not be used where rapid formation of callus is desired. This property may, however, be utilized in cases in which delay of ossification is desirable, as, for example, in the reconstruction of ankylosed joints. (3) Oxidized cellulose will not disintegrate and be absorbed in a closed area harboring infection. Only when the hemostatic effect of the cellulose offsets the disadvantage of postoperative drainage of the infection should it be used under such circumstances.

Clinical applications for purposes other than hemostasis are mentioned. The most important of these to the orthopaedic surgeon is the account of nerve suture by fibrin fixation. Whether this represents a significant improvement in technique will be determined only when the end results of the nerve sutures done by this method in World War II are compared with those of other methods. No figures of this type are available as yet.

The authors are to be congratulated for assembling so helpful a volume in such a succinct form.

TAKE UP THY BED AND WALK. David Hinshaw. New York, G. P. Putnam's Sons, 1948. $2.75.

Mr. Hinshaw discusses the problem of rehabilitation of the physically handicapped individual, but his story concerns essentially the progress of this work at the Institute for the Crippled and Disabled in New York City. The Institute did pioneer work in this field as far back as 1917, and in World War II provided training courses in rehabilitation procedures and techniques for members of the Armed Services. Courses for the handicapped are provided at the Institute in such skills as mechanical drawing, welding, jewelry making, watch repairing, sewing, and the like. As stated: "Vocational rehabilitation is the process of developing and restoring the handicapped individual, in terms of his total situation, to the fullest physical, mental, social, vocational and economic usefulness of which he is capable".

The importance is stressed of treating the patient as a whole, and not merely his disease. Special emphasis is laid upon orthopaedic conditions. The scope of physical medicine is discussed, and mention is made of the rehabilitation program sponsored by the Veterans Administration. The underlying theme of the book, however, is a plea for sympathetic understanding and help for the physically handicapped.

GUIDE FOR AN ADVANCED CLINICAL COURSE IN ORTHOPEDIC NURSING. New York, National League of Nursing Education, 1948. $0.60.

This pamphlet, prepared by the Subcommittee on Orthopaedic Nursing of the Committee on Postgraduate Clinical Nursing Courses, is No. 6 in a series dealing with the various branches of nursing which the qualified graduate nurse may enter. The objectives of a clinical course in orthopaedic nursing—namely, the "ability to utilize orthopedic principles in all nursing situations and to plan and carry out expert nursing for patients with orthopedic conditions"—are mentioned, and a teaching guide for such a course is set forth.